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Statistical Analysis of Blood Lead Levels of Children Surveyed in Pittsburgh, Pennsylvania: Analytical Methodology and Summary Results

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Final

Prepared for
Office of Policy Development and Research
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STATISTICAL ANALYSIS OF BLOOD LEAD LEVELS OF CHILDREN SURVEYED IN PITTSBURGH, PENNSYLVANIA: ANALYTICAL METHODOLOGY AND SUMMARY RESULTS

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Table of Contents

Table of Contents (con't)

List of Tables

List of Figures

Analysis of Blood Lead Levels of Children Surveyed in Pittsburgh Pennsylvania: Analytical Methodologies and Summary Report

Abstract

A survey was conducted in Pittsburgh, Pennsylvania to estimate the incidence of lead paint in housing and to develop a survey methodology that could be used in other metropolitan communities. A secondary objective of the survey was to determine whether a causal relationship could be found between blood lead levels of children aged 7 years or less, living in the surveyed dwellings, and the presence of lead paint. This report deals with the latter objective. For the children tested in Pittsburgh the incidence of elevated blood lead levels, defined as 40 micrograms of lead per 100 milliliters of blood or greater, was found to be less than one percent, which is too low to permit the establishment of a causal relationship. Since more than 80% of the tested children lived in dwellings containing lead, the low incidence of elevated blood lead levels makes it appear that the presence of lead paint does not necessarily result in children having elevated blood lead levels. There was a low correlation (6-15%) between the blood lead levels of the children and the fraction of lead bearing surfaces within their dwellings. There was a stronger correlation (40%) between the blood lead levels and the age of the dwellings in which the children resided. This correlation appeared to be independent of the lead paint levels in the dwellings.

This report presents a summary of the survey procedures, the blood lead measurement process and associated problems and the more significant results of the analysis of the housing/blood lead data obtained in

Pittsburgh.

Key Words: Blood; blood lead; elevated blood lead; children; housing; lead paint; lead poisoning; surveys.

I. INTRODUCTION

Lead poisoning of children is a serious national health problem. It has been estimated that as many as 500,000 children [1],* below the age of seven years, may have excessive body burdens of lead resulting from a variety of environmental exposures including lead in air, water, food, and dust.

It is generally believed that one important source of lead poisoning of children is lead paint in housing. In addition to the natural tendencies of young children to chew and teethe on non-food items, there is an abnormal tendency among some children, called "pica", which is an active consumption of non-food items. Dried, peeling paint on walls, woodwork and other accessible surfaces represents a health hazard to children who exhibit an interest or craving for such chewable materials especially if the paints contain lead compounds.

Although the health effects of low level body burdens of lead in children are not known, high body burdens result in severe neurological damage including mental retardation and in some cases, death. A primary diagnostic tool in determining the body burden of lead is the measurement of lead in blood.

The Department of Housing and Urban Development (HUD) is required by Title III of PL 91-695, the Lead Based Paint Poisoning Prevention Act of 1971, to determine the nature and extent of the lead paint poisoning hazard to children throughout the nation. As one of several related research efforts, HUD undertook a program of investigation into the numbers and

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*Numbers in brackets refer to references

geographical distribution of children under the age of seven with abnormally high levels of lead in their bodies and the nature and numbers of dwellings which constitute potential hazards by virtue of their lead paint content and physical condition.

The National Bureau of Standards (NBS) has provided technical assistance to HUD in this research area because of its capabilities in: housing related research; chemistry; mathematics; statistics and computer science. Under HUD sponsorship, NBS had previously estimated the national incidence of elevated blood lead levels among children age seven or less. The estimate, reported in NBS TN 746 [1], was based primarily on very limited child screening data, obtained from two community administered surveys, which provided too small a sampling to serve as a sound basis for an adequately valid estimate. In 1973, HUD requested NBS to develop a program to update and refine its previous estimates of the number of dwelling units constituting lead paint hazards. NBS responded by developing a housing survey methodology which included both the operational aspects and statistical and analytical functions of such a survey. The procedures were evaluated and refined by means of a field test in Washington, DC which was reported in NBSIR 74-426 [2].

Subsequent to the development of the NBS survey plan, HUD reviewed its own definitions of the lead paint hazard in housing and recognized the need for additional data which might prove the correlation between the lead paint content of housing and blood lead levels in children. NBS was therefore requested to modify its survey plan to include the screening of children for blood lead levels as well as surveying housing for lead paint. NBS was also requested to select a city in which to

carry out the survey and formalize the arrangements for its implementation.

The city of Pittsburgh, Pennsylvania was selected as the site for the survey, and the Allegheny County Health Department (ACHD) was chosen as the agent to conduct the survey. The ACHD is responsible for administering both public health and public housing functions in the city of Pittsburgh. The administrative control of the two major parts of the survey activity (housing and health measurements) by this one agency was a major selective factor. In addition, the ACHD was actively engaged in screening children by blood lead measurement as part of a Federal grant program to identify and treat children with lead poisoning. The ACHD had experienced staff, administrative control of a large city area and an enthusiastic desire to carry out the survey, all of which contributed to make Pittsburgh uniquely appropriate for the program.

In a contract arrangement between NBS and the ACHD a housing survey was conducted with the areas of responsibility defined as follows: NBS furnished the survey methodology, lead detection equipment, and training in the use of that equipment; monitored the inspection procedure; and prepared and analyzed the data base. The ACHD provided the staff required to administer the program and conducted the various survey operations including: inspection of dwellings for lead; collection of blood samples of children aged 7 years or less, and the analysis of those samples for lead.

This report describes those aspects of the survey which pertain to the collection and analysis of the blood samples and presents an analysis of the data. Other reports, being prepared by NBS, are directed to the housing aspects of the survey [3].

2. THE SURVEY APPROACH

The NBS/HUD sponsored "Pittsburgh Survey" is the only major statistically designed housing survey for lead paint hazards that has been carried out to date. The Center for Disease Control (CDC) of the Department of Health, Education and Welfare issues grants to Public Health agencies throughout the country for child screening programs that are basically limited to areas where high lead poisoning incidence is expected. Local programs identify so-called "lead-belts" by accumulating lead poisoning data submitted by neighborhood clinics and public health offices.

A goal of the survey was to obtain a representative sampling of the entire Pittsburgh area and not just identifiable "lead-belts". This was achieved by a housing selection strategy. Four thousand dwellings were selected randomly from a listing of the entire housing population of the city. This process was accomplished using a computer generated list of random numbers which were then used to select pages, columns, and lines from a Polk [4] directory of Pittsburgh that listed all the buildings by their addresses.

The ACHD contacted the occupants of the selected dwellings by means of direct mailings and follow-up telephone calls. Initial visits were limited to housing inspections for measuring lead content of interior and exterior surfaces and identifying other pertinent housing conditions and construction characteristics.

2.1 SELECTION OF CHILDREN

At the time of the first visit by the ACHD, occupancy by children

under seven years of age was determined and parents or guardians were requested to allow their children to be included in the blood testing program. Following this procedure, 800 children were identified as being eligible to participate in this program.

Full participation in the blood lead testing program could not be obtained since the participation was on a voluntary basis. The large number of refusals (about 40% of the eligible children) introduced a bias to the survey sample. Eventually 456 children were tested. The reasons for refusal were noted in order to assess their impact upon the randomness of the sample and the nature of the bias. Refusals by parents or guardians to allow their children to be tested were based on: the absence of lead paint in their homes as determined by the ACHD inspection team and the parent's reluctance to allow the blood collectors to take the child's blood because of unfamiliarity with the public health department.

Of the reasons given, those based upon the absence of lead paint in the dwellings were of the type that could bias the survey. Therefore the lead paint profiles of the dwellings of the tested children, the children who were not tested and of the entire surveyed population of Pittsburgh were compared on a room by room basis to determine what the differences were.

To date there is no specific index by which dwellings may be inter-compared with regard to the extent and degree of lead contamination. The decoration and painting of dwellings is a highly individual matter. The only direct way that dwellings may be compared is on a room by room basis and by the amount of lead paint on each surface type. The results of the comparisons of the 550 dwellings occupied by the 800 children are

shown for walls, windows and doors in Figures 1, 2, and 3 respectively, and the data from which these results were compiled are shown in Tables 1, 2, and 3. The results for baseboards obtained in the survey are so similar to the results for walls, windows, and doors that they are not included in this report.

The data shown in Tables 1-3 were obtained in the following manner. Readings were taken from each room in a dwelling with a portable x-ray fluorescence lead detector [5] at various accessible locations on different surface types such as walls, windows, doors, and baseboards. The readings were recorded and for each room a high value was established for each type of surface. A reading of 2 milligrams of lead per square centimeter is taken by convention to be an indication of significant lead contamination.

The high readings for each type of room for their respective surfaces were aggregated and averaged according to dwelling population, such as those of the tested children. These averaged readings are referred to as mean high readings. The distributions of such readings were found to be strongly skewed toward high values. The consequence of this is that the standard deviations may exceed their associated mean high values. One such distribution is shown in Figure 4 in the form of a histogram. In this figure the frequency distribution of the lead content of walls in 429 kitchens is shown for the dwellings of the tested children. The values range from zero to more than 20 milligrams of lead per square centimeter of wall surface. The mean value for this distribution is 3.3 and the standard deviation is 5.7;a value that exceeds the mean. Nevertheless the standard deviation may be used as a useful measure of the deviation of

Figure 1

Room by Room Comparison of Lead Content of Walls

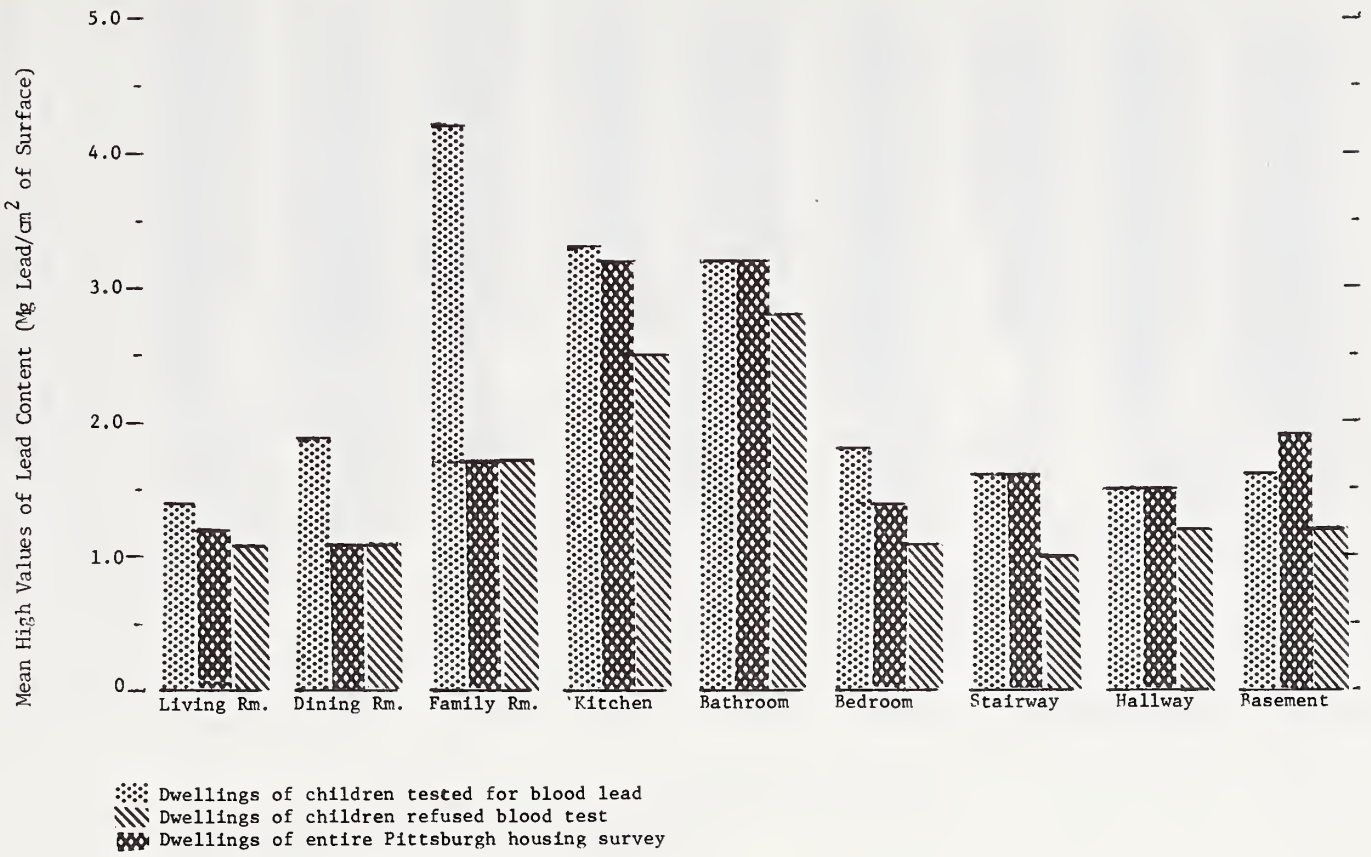


Figure 2

Room by Room Comparison of Lead Content of Windows

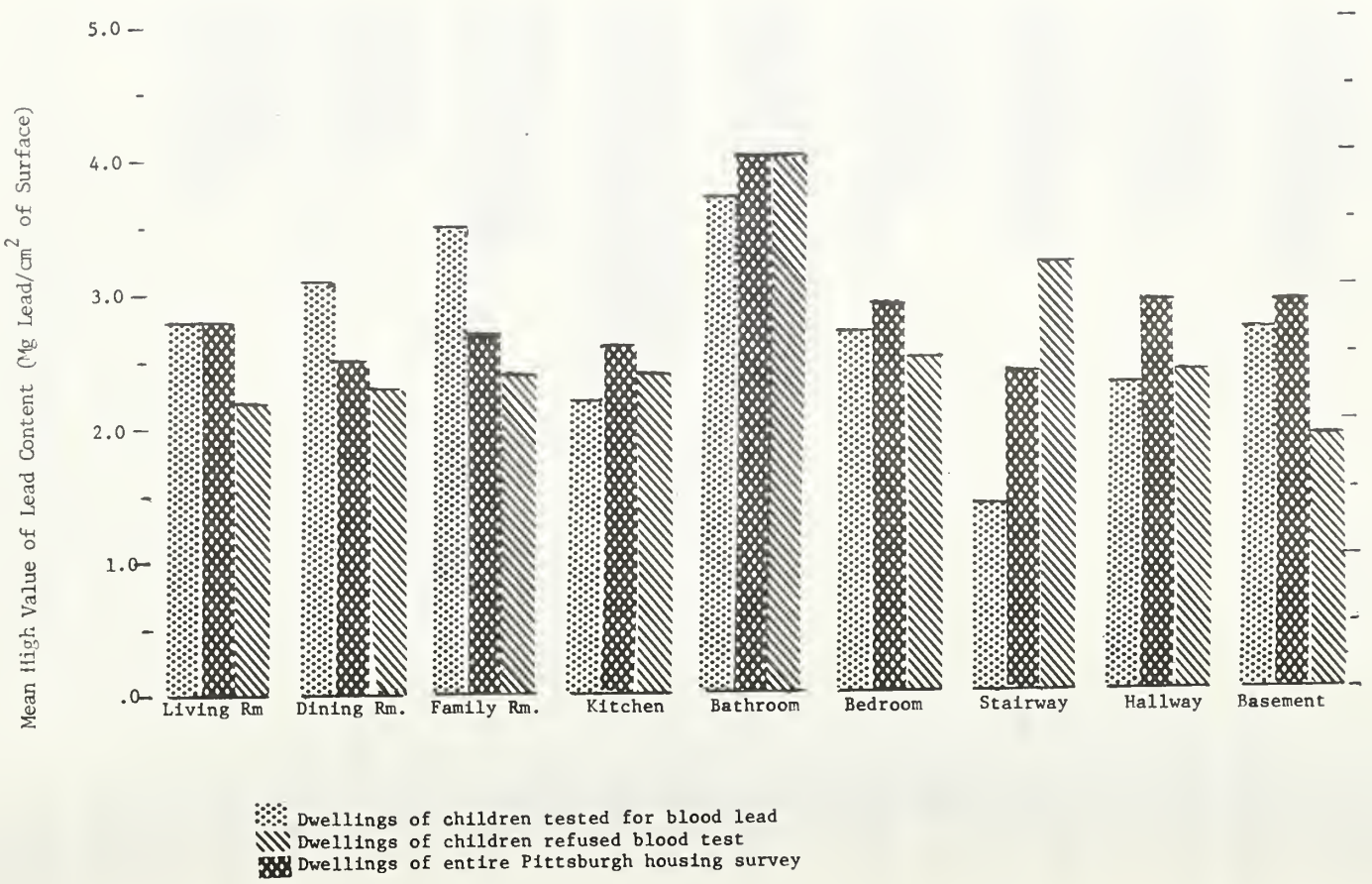


Figure 3

Room by Room Comparison of Lead Content of Doors

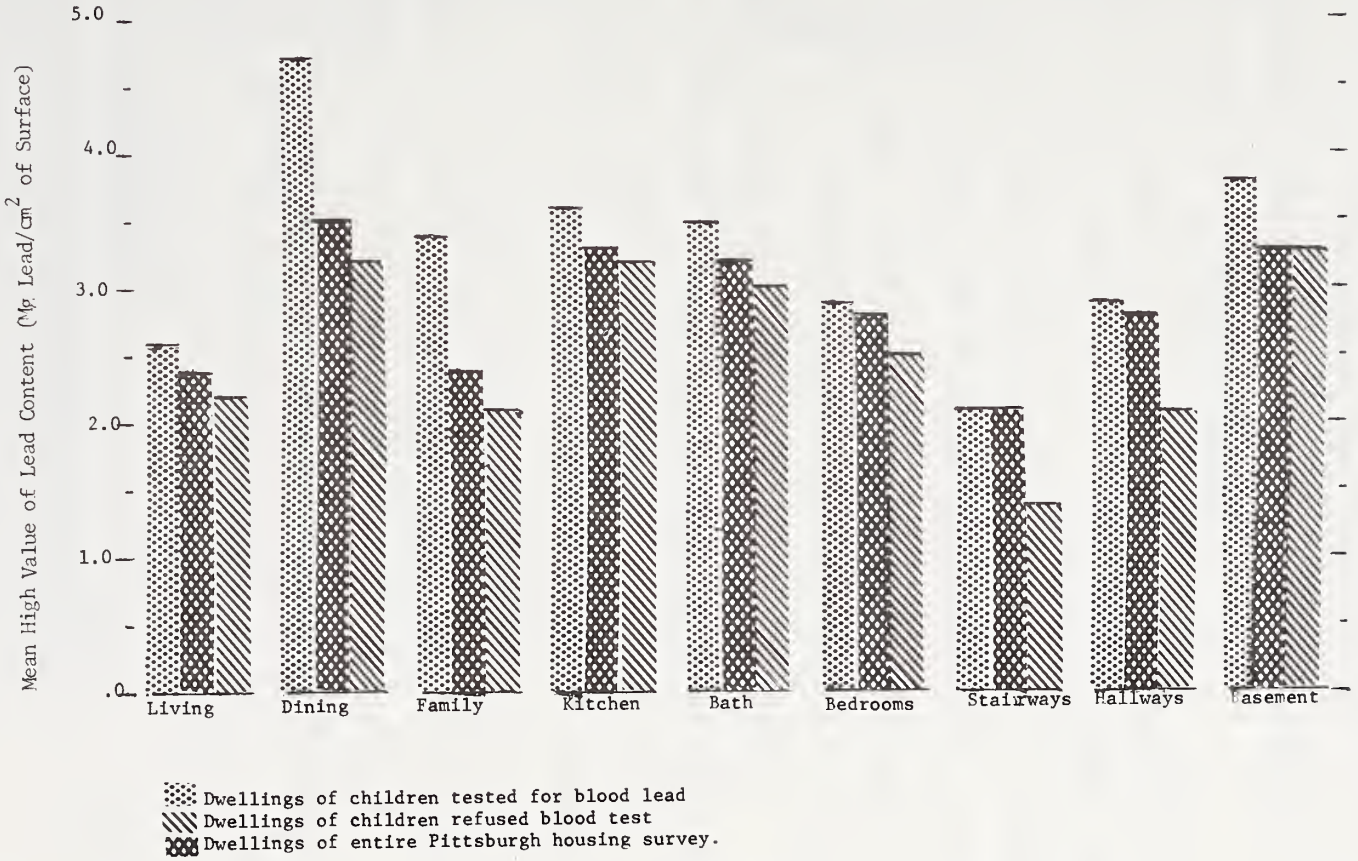
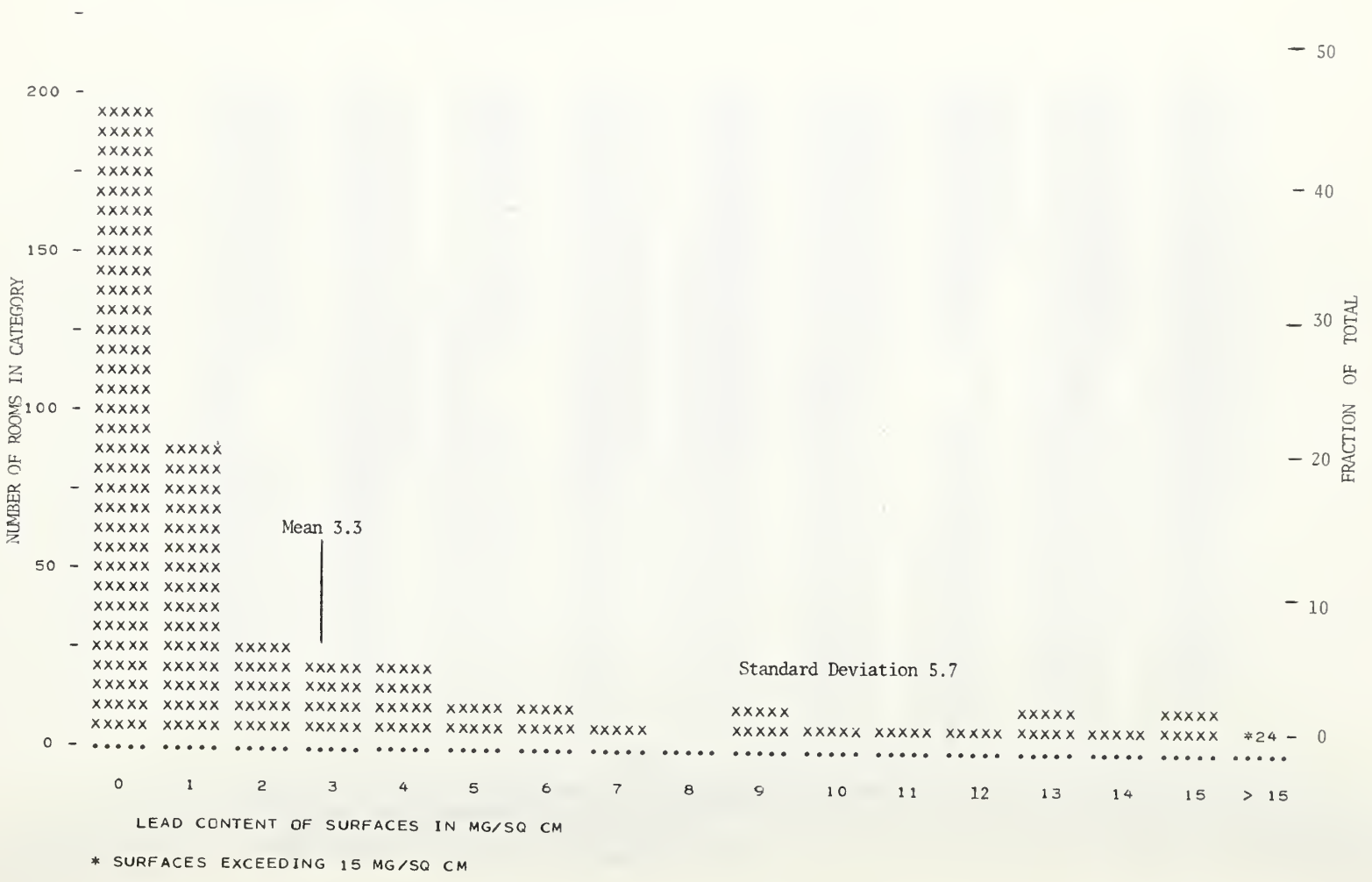


Figure 4

FREQUENCY DISTRIBUTION OF THE LEAD CONTENT OF KITCHEN WALLS OF THE DWELLINGS OCCUPIED BY THE TESTED CHILDREN



the lead values from the mean.

In the same distribution of 429 kitchens, the lead contents of 53, 24, and 12 rooms (12, 5 and 3% of the total respectively) exceeded the mean by 1, 2 and 3 standard deviations respectively. In Tables 1, 2, and 3 the standard deviations have been provided to serve as indicators of the broadness of the frequency distribution curves.

Mean readings were computed by using an aggregation process for each type of room. All of the readings for the surface of a specified type were used, not just the high readings. Because of placement of cabinets, heavy appliances and furniture some surfaces were inaccessible, so that not all rooms had an equal number of readings taken for each surface. In some rooms more high readings were taken than low readings, consequently some mean readings exceeded their associated mean high readings.

The room by room comparisons in Figures 1, 2, and 3 show that the tested children lived in dwellings that contained more lead than did the dwellings of both the total surveyed population and the dwellings of children who were not tested. The untested children lived in dwellings that contained less lead than did those of the surveyed population as a whole. By implication, the non-tested children (by living in dwellings that contain less lead than those of the tested children) are likely to have no higher, if not actually lower, blood lead levels than those of the tested children. Thus, while the sample of children may be biased because of refusals, the bias is in the direction of finding higher blood lead levels if, in fact, there is a relationship between lead levels in housing and children's blood lead levels.

As noted above, the housing and consequently the households were

Table 1

Room by Room Lead Content Data for Walls

OCCUPANCY CLASS: ALL — SURFACE TYPE: WALLS

	HIGH VALUE FOR SURFACE			ALL READINGS FOR SURFACE			HIGH VALUE FOR SURFACE 2 MG PB/SQ CM OR GREATER				ALL READINGS FOR SURFACE 2 MG PB/SQ CM OR GREATER			
	NO OF ROOMS	MEAN HIGH READING	STD DEV* OF HIGH READINGS	NO OF SURFACES	MEAN READING	STD DEV* OF READINGS	PCT OF RMS	NO OF ROOMS	MEAN HIGH READING	STD DEV* OF HIGH READINGS	PCT OF SURFACES	NO OF SURFACES	MEAN READING	STD DEV* OF READING
TESTED CHILDREN'S DWELLINGS														
LIVING	444	1.4	3.4	1721	.7	2.9	9	42	9.4	6.9	6	111	9.7	5.9
DINING	238	1.9	4.6	926	1.0	3.5	15	35	10.2	7.8	10	92	9.7	6.0
FAMILY	65	4.2	9.4	254	2.2	6.6	34	22	10.7	14.2	19	47	10.2	12.5
KITCHEN	429	3.3	5.7	1635	1.9	4.7	32	138	8.8	7.4	20	324	8.6	7.1
BATHROOM	426	3.2	5.9	1622	1.9	4.9	32	138	8.3	8.1	22	356	7.9	8.0
BEDROOM	869	1.8	4.4	3407	.8	3.5	14	121	9.3	8.4	8	265	9.9	8.0
STAIRWAY	222	1.6	3.5	526	.8	3.0	17	37	7.6	5.5	10	50	8.1	5.6
HALL	190	1.5	3.6	479	1.0	3.3	15	28	8.4	5.6	11	52	9.1	5.1
BASEMENT	75	1.6	2.5	270	.8	1.9	16	12	5.3	4.7	7	19	5.7	4.1
UNTESTED CHILDREN'S DWELLINGS														
LIVING	336	1.1	2.5	1290	.4	2.0	8	27	7.2	6.0	4	58	7.0	5.8
DINING	188	1.6	4.4	729	.7	3.1	12	22	9.1	10.1	7	52	8.1	8.6
FAMILY	51	1.7	3.6	199	1.0	3.0	18	9	6.8	6.6	9	18	8.2	6.2
KITCHEN	321	2.5	4.6	1225	1.5	3.9	25	79	8.4	6.3	16	199	8.1	6.3
BATHROOM	325	2.8	4.8	1224	1.7	3.9	30	99	7.7	6.3	21	263	7.1	5.6
BEDROOM	618	1.1	2.1	2436	.3	1.4	10	59	6.2	3.9	4	104	5.2	3.2
STAIRWAY	133	1.0	3.0	313	.4	2.3	9	12	7.7	7.2	6	20	6.5	5.9
HALL	100	1.2	3.3	280	.5	2.3	12	12	6.6	7.6	9	24	5.5	5.5
BASEMENT	54	1.2	1.5	203	.6	1.3	11	6	4.6	2.1	7	14	4.1	2.1
ALL DWELLINGS IN THE PITTSBURGH SURVEY														
LIVING	2768	1.3	3.0	10729	.6	2.6	9	251	8.1	6.8	6	618	8.3	6.7
DINING	1631	1.6	4.0	6305	.8	3.2	12	199	9.0	8.0	8	473	9.1	7.6
FAMILY	342	1.7	4.0	1297	.8	3.1	16	55	7.5	7.6	9	114	8.0	7.0
KITCHEN	2697	3.2	5.6	10309	1.8	4.5	29	791	9.1	7.4	19	1926	8.6	6.9
BATHROOM	2624	3.2	5.3	9976	2.0	4.5	34	901	8.0	6.8	24	2400	7.6	6.4
BEDROOM	4607	1.4	3.1	18067	.5	2.3	12	550	7.5	6.1	6	1111	7.0	5.5
STAIRWAY	1047	1.6	3.7	2437	.9	3.1	15	159	8.3	6.0	10	248	8.1	5.8
HALL	912	1.5	3.5	2424	.8	2.8	14	129	7.9	6.1	9	208	7.7	5.9
BASEMENT	445	1.9	3.8	1667	.9	2.9	16	71	7.1	7.6	8	131	7.4	7.4

ALL READINGS IN MG/SQ CM

*Highly skewed data may make the standard deviations exceed the mean value

Table 2

Room by Room Lead Content Data for Windows

OCCUPANCY CLASS: ALL — SURFACE TYPE: WINDOWS

	HIGH VALUE FOR SURFACE			ALL READINGS FOR SURFACE			HIGH VALUE FOR SURFACE 2 MG PB/SQ CM OR GREATER				ALL READINGS FOR SURFACE 2 MG PB/SQ CM OR GREATER			
	NO OF ROOMS	MEAN HIGH READING	STD DEV* OF HIGH READINGS	NO OF SURFACES	MEAN READING	STD DEV* OF READINGS	PCT OF RMS	NO OF ROOMS	MEAN HIGH READING	STD DEV* OF HIGH READINGS	PCT OF SURFACES	NO OF SURFACES	MEAN READING	STD DEV* OF READING
TESTED CHILDREN'S DWELLINGS														
LIVING	331	2.8	4.1	582	2.9	4.1	36	119	6.9	4.5	38	219	6.9	4.4
DINING	202	3.1	4.3	367	3.1	4.2	40	80	7.1	4.3	41	151	6.9	4.1
FAMILY	55	3.5	5.3	94	3.2	4.6	51	28	6.2	6.4	47	44	5.9	5.5
KITCHEN	334	2.2	3.5	515	2.3	3.4	34	114	5.6	4.2	36	183	5.7	3.8
BATHROOM	304	3.7	5.5	583	2.1	4.4	46	140	7.5	6.2	26	152	7.3	6.0
BEDROOM	757	2.7	4.6	1256	3.0	4.7	34	256	7.2	5.6	38	471	7.2	5.5
STAIRWAY	56	1.4	2.7	69	1.3	2.6	21	12	5.4	3.6	22	15	5.1	3.4
HALL	28	2.3	4.2	32	2.5	4.0	39	11	5.7	5.0	41	13	5.8	4.6
BASEMENT	38	2.7	3.5	82	2.1	2.9	42	16	6.0	3.0	37	30	5.3	2.6
UNTESTED CHILDREN'S DWELLINGS														
LIVING	233	2.2	3.6	411	2.3	3.8	30	70	6.4	4.1	30	125	6.8	4.3
DINING	128	2.3	3.9	213	2.5	4.0	32	41	6.3	4.9	34	72	6.3	4.7
FAMILY	35	2.4	4.0	64	3.0	5.0	31	11	6.7	5.0	38	24	7.4	6.0
KITCHEN	210	2.4	3.8	328	2.4	3.7	30	64	6.9	4.3	30	99	6.8	4.2
BATHROOM	210	4.0	6.6	221	3.9	6.4	38	79	9.9	7.6	37	81	9.9	7.5
BEDROOM	479	2.5	3.9	901	2.6	4.0	29	138	7.5	4.1	30	272	7.6	3.9
STAIRWAY	47	3.2	4.5	54	3.1	4.4	34	16	8.7	3.7	31	17	8.8	3.6
HALL	12	2.4	4.7	13	3.5	6.0	33	4	6.6	6.7	38	5	8.6	7.3
BASEMENT	31	1.9	2.7	76	2.3	3.0	32	10	4.8	3.0	41	31	5.0	3.0
ALL DWELLINGS IN THE PITTSBURGH SURVEY														
LIVING	1933	2.8	4.5	3417	2.9	4.5	34	650	7.6	4.9	35	1185	7.6	4.9
DINING	1195	2.5	3.9	2126	2.5	3.9	31	368	7.0	4.4	31	667	6.9	4.3
FAMILY	245	2.7	4.8	412	2.6	4.6	33	81	7.4	6.0	31	127	7.5	5.8
KITCHEN	1889	2.6	4.1	2990	2.9	4.3	34	637	6.9	4.7	36	1086	7.0	4.8
BATHROOM	1644	4.0	5.9	1826	3.7	5.7	45	738	8.3	6.4	42	762	8.3	6.4
BEDROOM	3705	2.9	4.4	6537	3.0	4.5	35	1286	7.4	4.9	36	2355	7.4	4.8
STAIRWAY	304	2.5	4.1	346	2.5	4.0	30	91	7.4	4.5	29	102	7.3	4.6
HALL	136	2.9	4.0	213	3.4	3.5	38	51	6.8	4.1	55	118	5.7	3.1
BASEMENT	236	2.9	4.2	583	3.0	4.1	41	96	6.4	4.8	44	254	6.2	4.5

ALL READINGS IN MG/SQ CM

*Highly skewed data may make the standard deviations exceed the mean value

Table 3

Room by Room Lead Content Data for Doors

OCCUPANCY CLASS: ALL — SURFACE TYPE: DOORS

	HIGH VALUE FOR SURFACE			ALL READINGS FOR SURFACE			HIGH VALUE FOR SURFACE 2 MG P8/SQ CM OR GREATER				ALL READINGS FOR SURFACE 2 MG P8/SQ CM OR GREATER		
	NO OF ROOMS	MEAN HIGH READING	STD DEV* OF HIGH READINGS	NO OF SURFACES	MEAN READING	STD DEV * OF READINGS	PCT OF RMS	NO OF ROOMS	MEAN HIGH READING	STD DEV* OF HIGH READINGS	PCT OF SURFACES	NO OF SURFACES	MEAN READING	STD DEV* OF READING
TESTED CHILDREN'S DWELLINGS														
LIVING	273	2.6	5.0	354	3.1	5.1	28	76	7.5	7.4	32	113	8.1	6.5
DINING	103	4.7	4.9	134	4.5	4.6	52	54	8.2	4.5	53	71	7.8	4.1
FAMILY	38	3.4	4.4	59	4.5	5.1	39	15	7.6	4.5	47	28	8.6	4.6
KITCHEN	356	3.6	4.6	551	4.0	4.9	44	158	7.2	4.8	48	267	7.5	5.1
BATHROOM	404	3.5	4.3	439	3.5	4.4	45	181	7.0	4.3	45	199	7.0	4.6
BEDROOM	776	2.9	4.2	1273	3.0	4.2	35	275	7.2	4.4	37	466	7.3	4.3
STAIRWAY	21	2.1	3.6	31	1.6	3.1	29	6	6.7	3.9	19	6	6.7	3.9
HALL	135	2.9	3.9	404	2.5	3.5	33	44	7.4	4.0	28	115	7.0	3.7
BASEMENT	48	3.8	3.6	91	3.3	3.1	48	23	6.7	3.3	38	35	6.5	2.8
UNTESTED CHILDREN'S DWELLINGS														
LIVING	209	2.2	3.7	271	2.3	3.7	25	52	7.1	4.7	25	69	7.2	4.5
DINING	79	3.2	5.0	105	3.5	5.5	33	26	8.5	5.9	33	35	9.2	6.4
FAMILY	32	2.1	3.4	42	2.1	3.1	25	8	6.9	4.0	24	10	6.6	3.5
KITCHEN	244	3.2	4.6	347	3.6	4.9	36	87	7.6	5.3	40	139	7.9	5.3
BATHROOM	300	3.0	5.0	319	3.2	5.3	29	86	8.9	6.1	29	94	9.3	6.5
BEDROOM	542	2.5	3.9	946	2.7	4.1	27	147	7.8	4.2	27	260	8.2	4.3
STAIRWAY	19	1.4	3.6	27	1.2	3.0	11	2	9.2	9.4	7	2	9.2	9.4
HALL	72	2.1	3.5	185	1.4	2.7	18	13	8.7	3.3	12	23	7.5	3.5
BASEMENT	37	3.3	3.3	78	2.7	2.9	54	20	5.6	2.9	46	36	5.2	2.5
ALL DWELLINGS IN THE PITTSBURGH SURVEY														
LIVING	1909	2.4	4.1	2623	2.6	4.2	27	511	7.4	5.2	29	765	7.6	5.1
DINING	745	3.5	4.6	1050	3.6	4.7	41	305	7.6	4.7	43	450	7.6	4.8
FAMILY	238	2.3	3.8	357	2.4	3.9	24	57	7.6	4.7	25	90	7.8	4.5
KITCHEN	2141	3.3	4.6	3308	3.6	4.7	38	817	7.6	4.9	42	1374	7.8	4.8
BATHROOM	2433	3.2	4.8	2621	3.3	4.9	35	841	8.0	5.4	35	918	8.1	5.5
BEDROOM	4107	2.8	4.2	7110	2.9	4.2	32	1303	7.6	4.4	33	2325	7.8	4.4
STAIRWAY	110	2.1	3.5	134	2.1	3.5	25	28	6.6	4.5	23	31	6.9	4.8
HALL	643	2.8	4.0	1785	2.3	3.6	30	191	7.7	4.1	25	438	7.5	4.0
BASEMENT	321	3.3	3.9	604	3.2	3.8	47	151	6.3	3.9	47	285	6.1	3.8

ALL READINGS IN MG/SQ CM

*Highly skewed data may make the standard deviations exceed the mean value

selected on a random basis. Children in households having only one child were therefore also selected on a random basis. However, any number of eligible children in each household were allowed to participate in the program and since siblings were not individually selected on a random basis, their inclusion introduces a small statistical bias. On the average in this program there were 1.5 children tested per household.

3. BLOOD SAMPLING

The blood collection procedure employed by the ACHD was comprised of the following essential steps. The child's finger was cleansed with a cotton swab to both disinfect the finger tip and to remove dirt and grime which might contain lead particles or other interfering contaminents. The finger tip (usually the index finger) was then punctured with a sterile needle and blood was forced from it by gentle pressure on the finger on both sides of the puncture. Several drops of blood were elicited and wiped away with sterile swabs. Approximately 0.25 milliliters were then drawn into a sterile capillary tube. A clean swab was finally pressed to the puncture to stop the bleeding and a simple bandage was applied. This procedure is described in greater detail in Appendix IA. Various factors combine to make this procedure of critical importance in obtaining valid blood lead data. The principle factors are: the small size of the blood samples; contamination of the blood samples during collection; and alteration or contamination of the samples after collection and prior to chemical analysis for lead.

3.1 BLOOD SAMPLE SIZE

Large blood samples of 5 to 10 milliliters are drawn from children only when absolutely necessary and only by personnel who are specifically

qualified and licensed to carry out such procedures. The sampling of blood by finger puncture is essentially hazard free; requires a minimal level of experience and qualification of the clinician; is much less expensive in terms of the cost of disposable equipment; is much more readily performed in the patient's home; and is therefore the method of choice for blood screening programs or surveys.

The blood sample size used in this survey was limited to 0.25 milliliters (250 microliters* or about 1/120 fluid ounce). This small sample size, along with the low level of lead being sought (80-100 nanograms**) greatly magnifies the effects of sample contamination and strains the limits of the analytical procedure's accuracy and precision.

3.2 BLOOD SAMPLE CONTAMINATION

Extensive experience of public health agencies, including the ACHD, has shown that failure to rigorously follow a prescribed method for collecting blood samples results in false positives, that is, lead analyses that erroneously indicate that the subject child has an elevated blood lead level. In most cases, such children, when retested using approved and carefully implemented sampling procedures, are found to have blood lead levels in the normal range. The cause of false positives is usually assumed to be contamination of the blood sample rather than systematic errors in the laboratory chemical analysis of the collected samples.

The ACHD tested its supplies and equipment (see Appendix IB1) and

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*1 microliter = one-millionth liter or 34 millionths fluid ounce
**1 nanogram = one-billionth gram or 35 million millionths ounce avoirdupois

did not find serious lead contamination potential from these sources. However, NBS tested the same types of supplies and equipment and found them to contain trace levels of lead (see Appendix IB-2). Thus, a potential may exist for contamination by the supplies and equipment used during the blood collection, but it is not possible to estimate how much actual contamination may occur in practice.

As a part of the ACHD survey effort, thirty-seven samples of household dust and outdoor soil were taken in Pittsburgh (see Appendix IC). From the lead values obtained it is evident that the environments in which the blood samples are taken can contribute enough lead to seriously contaminate the blood samples. The households dust samples ranged from less than 1 to as much as 230 micrograms* of lead per gram of dust while the dirt samples ranged from 200 to more than 4000 micrograms of lead per gram of dirt. From these values, an estimate can be made of the amount of lead that may be found in average dust and dirt films. For convenience 1 gram of dirt is assumed to occupy a volume of 1 cubic centimeter.

If a dust film is assumed to be 1/100 millimeter (.0004 inch) in thickness, it could contain 10 or more nanograms of lead per square centimeter while a dirt film of similar dimensions could contain over 200 nanograms These amounts represent a serious risk of contamination since they are of the same order of magnitude as the amounts being sought in the blood sample. Elevated blood lead levels (EBL) were designated by ACHD to be 40 micrograms of lead or more per 100 milliliters of blood, which amounts to 100 nanograms lead or more per blood sample of 250 microliters.

3.3 BLOOD SAMPLE ALTERNATION

NBS has found that even when blood samples are frozen, at about

*1 microgram = 1 millionth gram = 1000 nanograms.

-15°C, significant dehydration occurs if the samples are stored for several weeks (see Appendix ID). The storage containers used by the ACHD in the blood collection process were tubes made of polyethylene or polypropylene. Their caps do not close by friction and a partial vacuum must be induced during capping, to insure that the closure will be hermetic.

Dehydration of the blood samples increases the blood density. Since the blood lead levels are defined in terms of weight of lead per volume of blood the interpretation of such measurements are affected by a positive error. The apparent levels of lead will increase as the sample is dehydrated.

Dehydration is reduced but not eliminated by freezing the blood samples prior to analysis.

Another potential source of error is the analysis of clotted blood. Clotting occasionally occurs and makes the sample non-uniform in density. As it is customary to subdivide the blood in the collection tube, into smaller samples for duplicate analyses, it is unlikely that the subdivided samples are comparable to the bulk composition. The clotted portions and fluid portions are likely to contain different fractions of lead.

The ACHD laboratory requested new samples when this occurred.

4. ACHD BLOOD LEAD ANALYSIS PROCEDURE

4.1 GENERAL PROCEDURES

The ACHD blood samples were analyzed by a commercial clinical laboratory in Pittsburgh (Pittsburgh Laboratory). This laboratory employed a modified Delves Cup Atomic Absorption Spectrophotometric procedure which is a micro analytical technique. Macro (large scale)

procedures were precluded by the small size of the blood samples. This procedure was originally developed by H. T. Delves and modified and improved upon by others including D. Olson and I. Jatlow [6] and is described in detail in the literature.

Appendix II presents the procedure employed by the Pittsburgh Laboratory. The method essentially consists of partially oxidizing the sample with hydrogen peroxide, volatilizing the sample with an air-acetylene flame and aspirating the decomposition products into a nickel absorption tube situated in the flame. By noting an absorption peak compared with peaks obtained by using reference standards, the amount of lead that was in the sample may be determined.

4.2 VALIDATION OF ANALYTICAL RESULTS

Due to the low level of lead present in the blood samples, accurate analyses are often difficult to obtain. Yet, in screening programs, accurate analyses are necessary if the results are to be trusted and interpreted meaningfully.

Two strategies for validation were adopted to substantiate the findings of the Pittsburgh Laboratory. The first strategy involved the collection of duplicate samples of blood from about 10% of all the children tested, and having these samples analyzed by both Pittsburgh and NBS chemists respectively. The analytical methods employed differed greatly in methodology and in realizable absolute accuracy and precision.

The other strategy was to have porcine blood laden with various but very accurately known amounts of lead analyzed by both ACHD and NBS These strategies are described below.

4.2.1 DUPLICATE CHILDREN'S BLOOD SAMPLES

Duplicate blood samples of 0.25 milliliters each were drawn from 54 children. One sample was sent, as usual, to the Pittsburgh Laboratory. No indication was provided to the laboratory that the sample was unusual in any way. The other sample was frozen in dry ice and sent to NBS for analysis. NBS analyzed these samples by an isotopic dilution mass-spectrometric method, which is described in Appendix III.

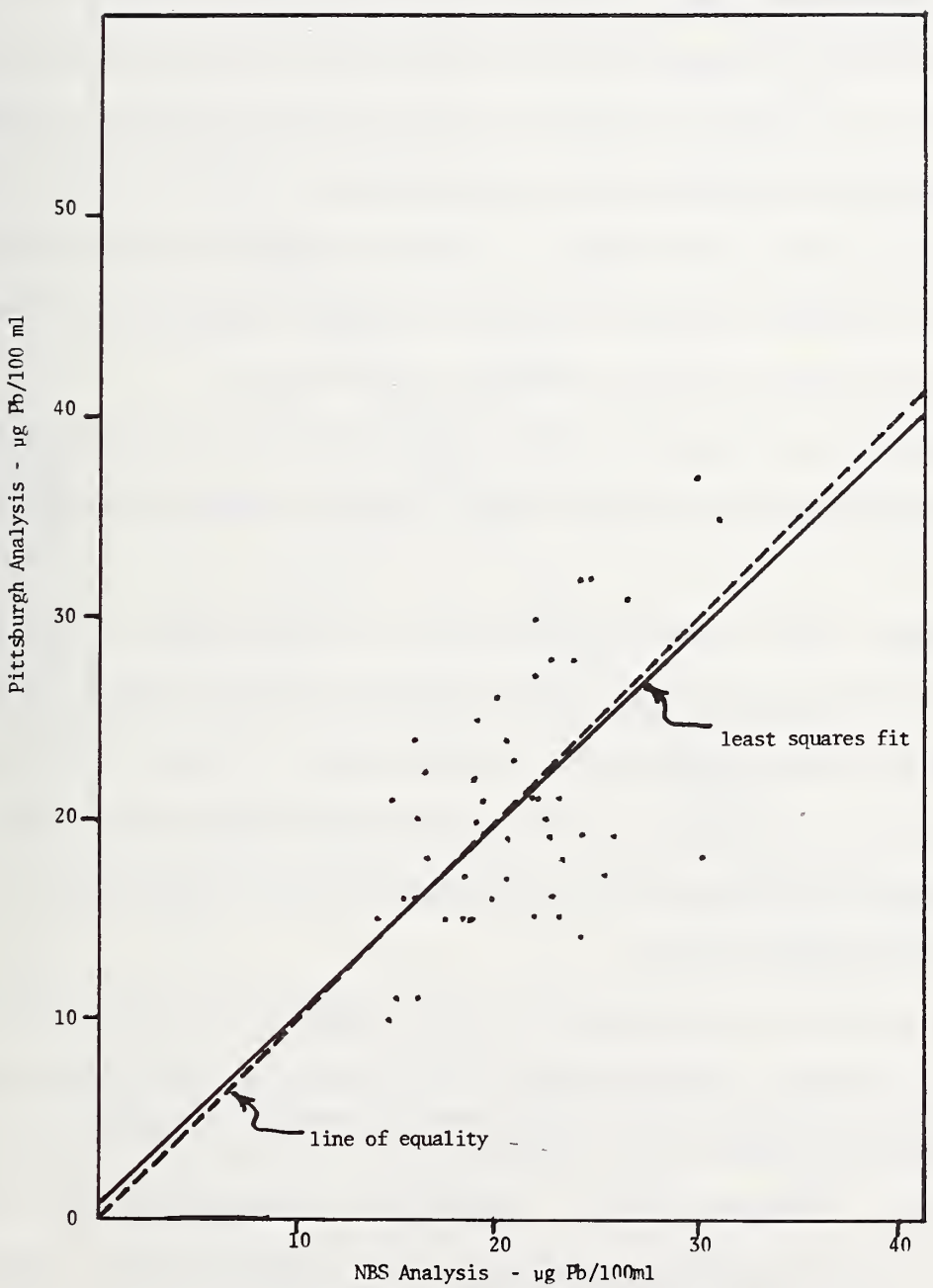
The results of the duplicate analyses of children's blood are shown in Figure 5. The NBS results are indicated along the abscissa, while the Pittsburgh laboratory values are indicated along the ordinate. A "line of equality" is shown in this figure. The data points that fall upon this line indicate agreement between the results obtained by the Pittsburgh laboratory and by NBS. The Pittsburgh laboratory results were higher or lower than the NBS results according to whether the data points shown are above or below this line. The less the data points deviate from this line the better the agreement. The vertical deviations of the data points from the "line of equality" provide a measure of the precision of the Pittsburgh laboratory's analyses. Another line labeled "least squares fit" is shown as the best straight line to fit the data. It may be noted that this line does not deviate much from the "line of equality".

4.2.2 PORCINE BLOOD STANDARD SAMPLES

Porcine blood lead reference standards being prepared and evaluated by NBS as part of a program relating to clinical standards were made available for use in the Pittsburgh survey. The lead in the blood was obtained from pigs which had been fed lead bearing foods. Blood samples with differing levels of lead were prepared by blending the blood samples

Figure 5

Comparative Analyses of Duplicate Samples of Children's Blood by NBS and the Pittsburgh Laboratory



from different pigs in varying proportions. The resulting levels of lead were determined by exhaustive macro-analytical procedures. These samples were used as porcine blood lead standards. Standard samples containing lead in the range of 17 to 34 and some at 105 micrograms per 100 milliliters of blood were used. Unfortunately blood samples having lead between 40 and 70 micrograms per 100 milliliters were not available.

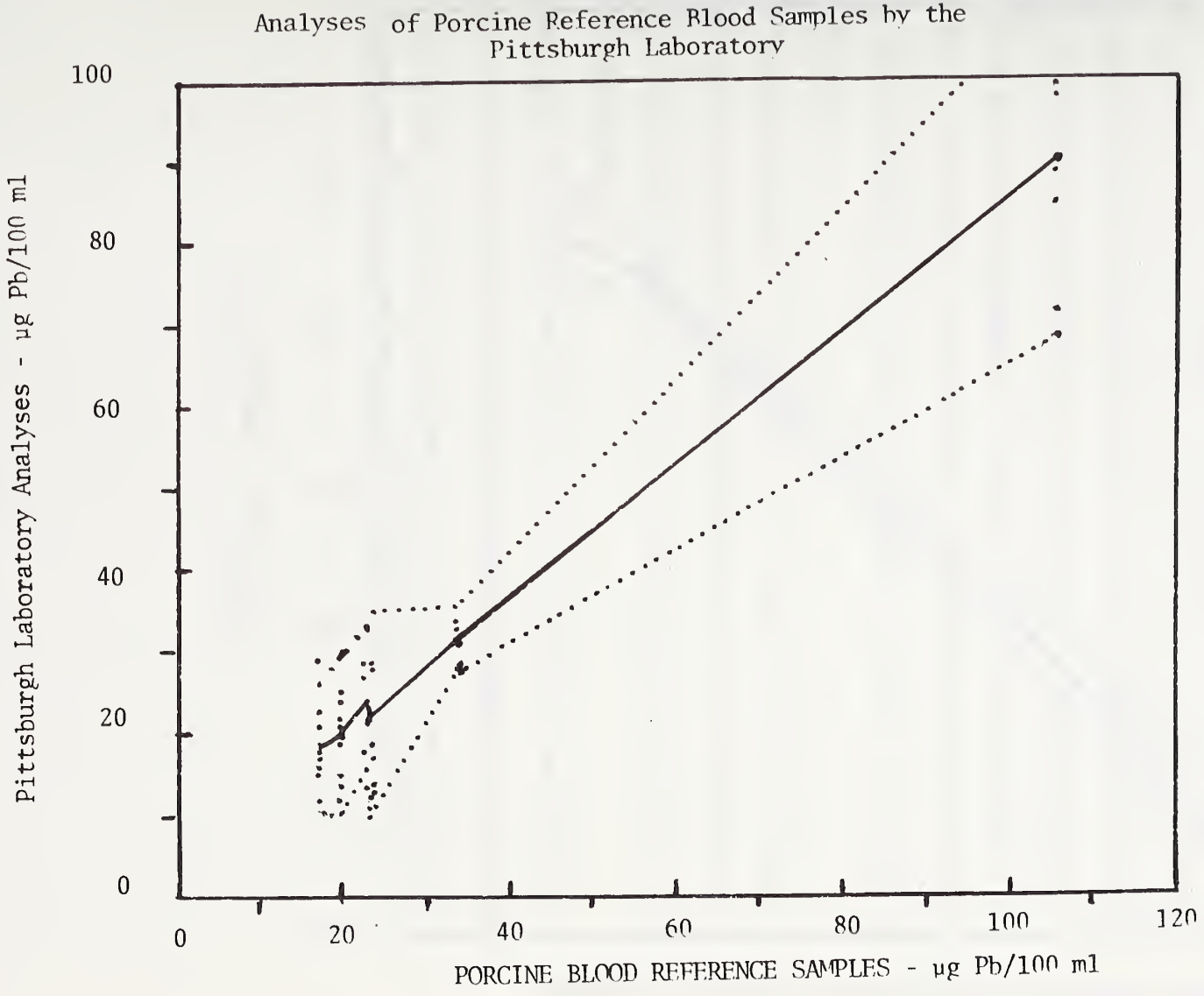
Six to ten standard specimens at each concentration were prepared by subdividing the porcine blood standard samples and were made up to resemble children's blood samples. They were provided with fictitious names and residence addresses, and were included along with children's blood sent to the Pittsburgh laboratory for analysis.

Similarly, six standard samples of porcine blood, at each of three concentrations, were anlayzed at NBS in the same manner as the children's blood.

Figures 6 and 7 show the comparisons of these results. Figure 6 shows the Pittsburgh results of the analyses of porcine blood samples compared with NBS porcine standard sample values. Figure 7 shows the NBS results of the analyses of the porcine blood samples by the NBS micro-isotopic dilution method as compared with the known values of the NBS porcine standard samples.

The analytical determinations of the subdivided portions of the porcine blood lead standard samples were averaged and the mean values of the determinations of the Pittsburgh laboratory and NBS respectively are shown in Figures 6 and 7. These lines are referred to as "mean lines". For the subdivided portions of each standard sample, the amount that the individual determinations deviate from the mean is a measure of

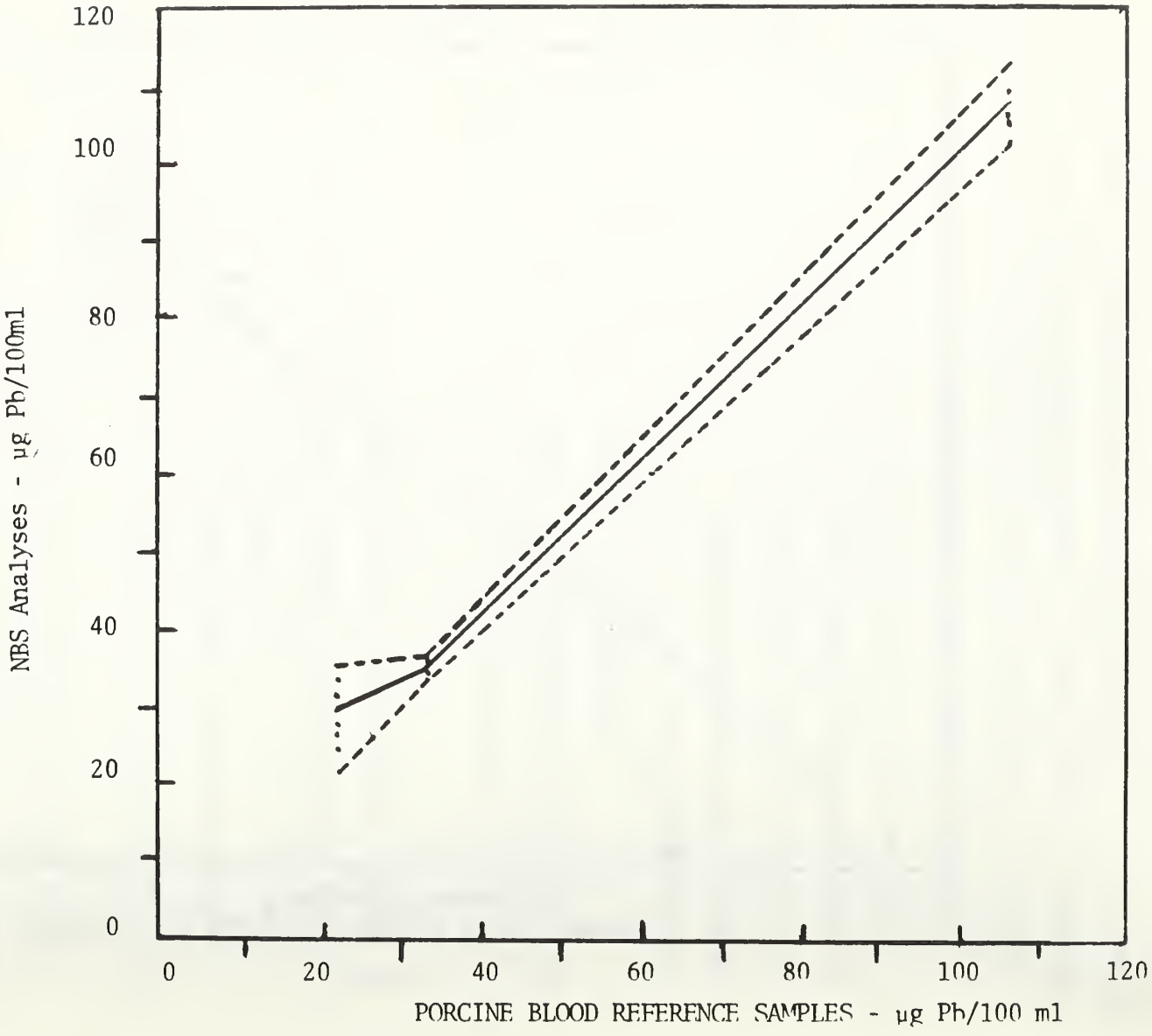
Figure 6



Solid line = Mean
Dashed line = 2 S limits

Figure 7

Analyses of Porcine Reference Blood Samples by NBS



Solid line = Mean
Dashed line = 2 S limits

the reproducibility or precision of the analyses. The mean value is the basis of the measure of accuracy. Specifically the amount that the mean deviates from the true value, in this instance, from the "line of equality", is a measure of the accuracy of the analysis. In Figures 6 and 7 the "line of equality" is implicit and is the line that connects equal values on both the horizontal and vertical axes. For the standard sample having the lead level of 34 micrograms per 100 milliliters, the mean value in Figure 6 is 5% low and the range of values is 20%. It is reasonable to assume that in the region of 40 micrograms approximately the same conditions apply. The corresponding NBS accuracy and range of values is 2% high and 4% respectively.

The solid lines shown in Figures 6 and 7 connect the mean values obtained for the respective subdivided samples. The dashed lines connect the respective limits which are twice the sample standard deviation above and below the means.

Based upon the determinations made in the comparative analysis of childrens blood and the porcine blood lead standard samples, the accuracy of the Pittsburgh laboratory is apparently adequate to determine whether blood lead levels are above or below the 40 μg/100 ml. level.

5. RESULTS, CONCLUSIONS AND SUMMARY

In the discussion below, the blood lead levels are expressed in units of micrograms per 100 milliliters and the definition of an Elevated Blood Lead Level (EBL) is 40 micrograms per 100 milliliters of whole blood or more.

A frequency distribution of the blood lead levels after retest of all the children who were tested in this survey, is shown in Figure 8. In this histogram the vertical bar represents the number of children (and fraction of all the children) whose blood lead levels were contained in the interval between the value posted below the bar and the next higher value, 5 micrograms per 100 milliliters higher. For example, 135 children had blood lead levels in the range of 15 to 19.9. It should be noted that the distribution is skewed toward the higher values after retest, only three children had lead levels exceeding 40 micrograms.

The same data are shown in Table 4 in the form of a cumulative distribution. In each percentile, the percent and number of children is shown whose lead levels do not exceed the stated value.

Of the 456 children tested all but 15 of them had blood lead levels that were found to be below the EBL defined above. Fourteen of the fifteen children (Table 5) were retested and all but two of these were then found to be below the EBL level. One of these two children with elevated blood lead levels was placed under surveillance to determine the source of lead. The other child, aged 8 years and retarded since an early age, had a blood lead level of 75 as confirmed by a macro analysis procedure and was treated for lead poisoning. The fifteenth child could not be located and thus was unavailable for retest. The

Table 4

Cumulative Distribution of the Tested Children's Blood Lead Levels

Percent of Samples within Blood Lead Range	Blood Lead Range (µg/100 ml)	Number of Samples in Range
10	0-13.6	46
20	0-15.5	91
30	0-17.3	137
40	0-18.8	182
50*	0-20.7	228
60	0-22.4	274
70	0-24.3	319
80	0-26.9	365
90	0-30.6	410
95	0-33.6	433
99	0-38.0	451
99.3	0-39.9	453
100	0-73.0	456

*Median

Table 5

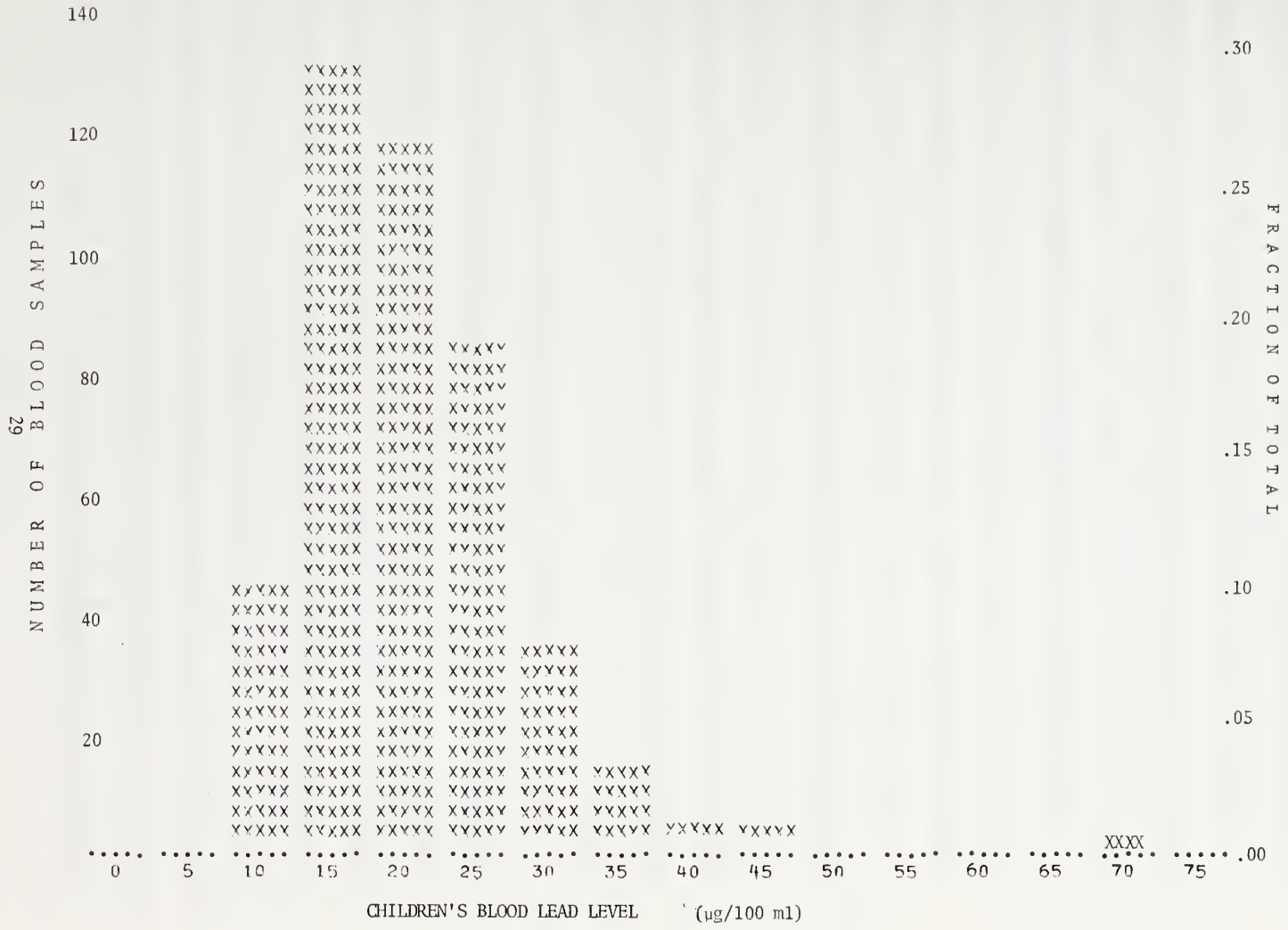
Children's Elevated Blood Lead Levels at Screening and Results after Retest

Child	Screening Micro µg/100 ml	Repeat Micro µg/100 ml	Macro* µg/100 ml	Case Status
1	45	26		Closed
2	73	73	75	
3	42	35		Closed
4	43	27		Closed
5	45	38		Closed
6	41	28		Closed
7	46	34		Closed
8	42	38		Closed
9	47	35		Closed
10	59	28		Closed
11	42	19		Closed
12	43	Can't be located		
13	40	21		Closed
14	50	48	43	
15	41	32		Closed

*Macro blood sample size is 10 milliliters

Figure 8

Frequency Distribution of the Tested Children's Blood Lead Levels



child's blood data is retained in this report as a case of EBL.

In Appendix IV various possible causes are discussed for the predominantly lower blood lead levels of these children after retest, with the conclusion that most of the initial values that were high were due to the inherent limitations of accuracy for the analytical method.

Some of the statistics for the Pittsburgh survey are summarized as follows: Of the 4000 randomly selected dwellings, 3300 were fully inspected for the presence of lead paint, the remainder were at least partially inspected. Of the fully inspected dwellings, 500 had 800 children in the target age range. The 456 children ultimately tested for elevated blood lead levels occupied 300 of the these dwellings.

Although 391 of the tested children (85.7%) lived in dwellings that contained at least one surface containing lead at a level of 2 mg/square centimeter or more (see Figure 7), the incidence of confirmed blood lead levels was less than 1%. Nevertheless, meaningful statistical analyses of the data were performed. The results of those analyses are discussed below.

Most of the blood lead levels (99%) were found to be below the EBL threshold, and since experience has shown that the analytical precision is significantly lower at the lower lead levels (see Figure 6), the individual blood lead values are of limited accuracy. Nevertheless, the number of blood lead samples is sufficiently large to permit trend analysis and the exploration of interrelationships between various parameters by statistical techniques. Extensive statistical analyses were performed by computer on the blood lead data and the most significant findings are reported below.

The mean and median blood lead levels of the tested children as categorized by their age and sex in combination with the age of the dwelling in which they live in shown in Table 6. From this table it may be noted that children under 1 had lower lead levels than those above 1. The median value for children under 1 in all dwellings was 16 while for those above 1 was 22. In the housing constructed after 1959 no significant differences in lead levels was found according to children's age. No significant difference in blood lead levels were found between males and females; the median values being 22 and 21 respectively.

The blood lead levels of the children, according to the fraction of surfaces that exceeded a value of 2 milligrams of lead per square centimeter is shown in Figure 9. The solid line shows blood lead levels as a function of fraction of lead contaminated surfaces which were in good condition. The dashed line shows the blood lead levels as a function of the fraction of the surfaces which were in poor condition, namely surfaces with loose, peeling or chalking paint. The relation between blood lead levels and the fractions of lead contaminated surfaces is not strong; the correlation coefficient is less than 15%. The blood lead levels increase only slightly with an increasing fraction of surfaces contaminated with lead and are a bit higher in dwellings whose surfaces are in poor condition. This finding applies only to the older homes since the newer homes have, at most, 20% of their surfaces contaminated with lead.

The distribution of the children's blood lead levels according to the year of construction of the dwelling in which the children live and the highest lead reading in the dwelling is shown in Table 7. From the data in this table and Table 6 above, the conclusion may be drawn that

TABLE 6

DISTRIBUTION OF BLOOD LEAD LEVELS BY AGE AND SEX OF CHILD AND BY THE AGE OF THE DWELLING

AGE OF CHILDREN	MALE NUMBER*	MALE MEDIAN	MALE MEAN	MALE STD DEV	FEMALE NUMBER*	FEMALE MEDIAN	FEMALE MEAN	FEMALE STD DEV	BOTH SEXES NUMBER*	BOTH SEXES MEDIAN	BOTH SEXES MEAN	BOTH SEXES STD DEV
PRE-1940 CONSTRUCTION												
UNDER 1	6	21.5	21.2	4.6	8	17.0	18.6	6.6	14	19.5	19.7	5.8
1	17	17.0	19.8	6.0	23	22.0	22.2	6.1	41	20.0	21.3	6.1
2	24	24.5	25.1	6.5	25	23.0	23.9	7.5	50	24.0	24.7	7.0
3	29	21.0	22.1	6.1	29	22.0	23.9	5.6	59	22.0	23.3	6.1
4	31	22.0	23.1	5.7	24	22.5	22.9	6.7	56	22.0	23.2	6.2
5	43	23.0	23.1	7.1	24	21.0	21.7	7.2	67	23.0	22.6	7.1
6	15	20.0	21.5	7.1	17	18.0	19.5	4.3	33	19.0	20.3	5.7
7	8	21.0	19.4	4.9	6	16.5	17.5	6.6	14	19.0	18.6	5.5
8***	5	22.0	31.4	23.4	12	18.0	17.7	4.6	17***	20.0	21.8	13.9
ALL AGES**	178	22.0	22.8	7.4	168	21.0	21.8	6.5	351	22.0	22.4	7.0
1940-1959 CONSTRUCTION												
UNDER 1	2	16.0	16.0	7.1	2	12.0	12.0	1.4	4	12.0	14.0	4.8
1	9	26.0	27.4	10.0	4	18.5	19.5	2.4	13	23.0	25.0	9.1
2	5	16.0	17.4	6.9	6	21.0	20.0	5.1	11	20.0	18.8	5.8
3	4	20.0	20.7	3.9	6	17.5	21.2	8.5	10	19.0	21.0	6.7
4	3	16.0	18.3	4.0	5	20.0	19.6	5.7	8	18.0	19.1	4.9
5	4	25.5	24.7	6.7	5	25.0	24.8	6.5	9	25.0	24.8	6.2
6	2	18.0	18.0	1.4	4	19.0	23.5	9.7	6	19.0	21.7	8.0
7	0	.0	.0	.0	1	15.0	15.0	.0	1	15.0	15.0	.0
8												
ALL AGES**	29	21.0	22.0	8.0	33	19.5	20.6	6.6	62	19.5	21.3	7.3
POST 1959 CONSTRUCTION												
UNDER 1	2	15.5	15.5	3.5	1	16.0	16.0	.0	3	16.0	15.7	2.5
1	2	17.5	17.5	2.1	3	19.0	19.3	4.5	5	19.0	18.6	3.5
2	1	16.0	16.0	.0	1	16.0	16.0	.0	2	16.0	16.0	.0
3	1	16.0	16.0	.0	2	21.5	21.5	.7	3	21.0	19.7	3.2
4	3	17.0	15.3	3.8	4	16.5	17.0	1.4	7	17.0	16.3	2.6
5	2	13.0	13.0	1.4	2	10.5	10.5	2.1	4	12.0	11.7	2.1
6	1	10.0	10.0	.0	2	20.0	20.0	8.5	3	14.0	16.7	8.3
7												
8	1	23.0	23.0	.0	2	28.0	28.0	.0	3	28.0	26.3	2.9
ALL AGES**	13	16.0	15.6	3.6	17	19.0	18.7	5.5	30	16.0	17.4	4.9
ALL DWELLINGS												
UNDER 1	10	19.0	19.0	5.2	11	15.0	17.2	6.2	21	16.0	18.0	5.7
1	28	19.0	22.1	8.1	30	21.5	21.6	5.6	59	20.0	21.9	6.8
2	33	23.0	23.1	6.9	32	22.0	22.9	7.2	66	22.0	23.2	7.1
3	36	21.0	22.1	5.8	37	22.0	23.3	6.0	74	21.0	22.9	6.1
4	38	21.0	21.9	5.9	34	20.5	21.8	6.4	73	21.0	22.0	6.1
5	50	23.5	23.0	7.1	32	21.0	21.4	7.4	82	23.0	22.4	7.2
6	19	20.0	20.6	6.9	24	18.5	19.9	5.8	44	19.0	20.1	6.2
7	9	21.0	19.3	4.6	7	16.0	17.1	6.1	16	18.0	18.4	5.2
8	7	23.0	29.6	19.4	14	19.0	19.2	5.6	21	21.0	22.7	12.6
ALL AGES**	230	22.0	22.3	7.4	221	21.0	21.4	6.5	456	21.0	21.9	7.0

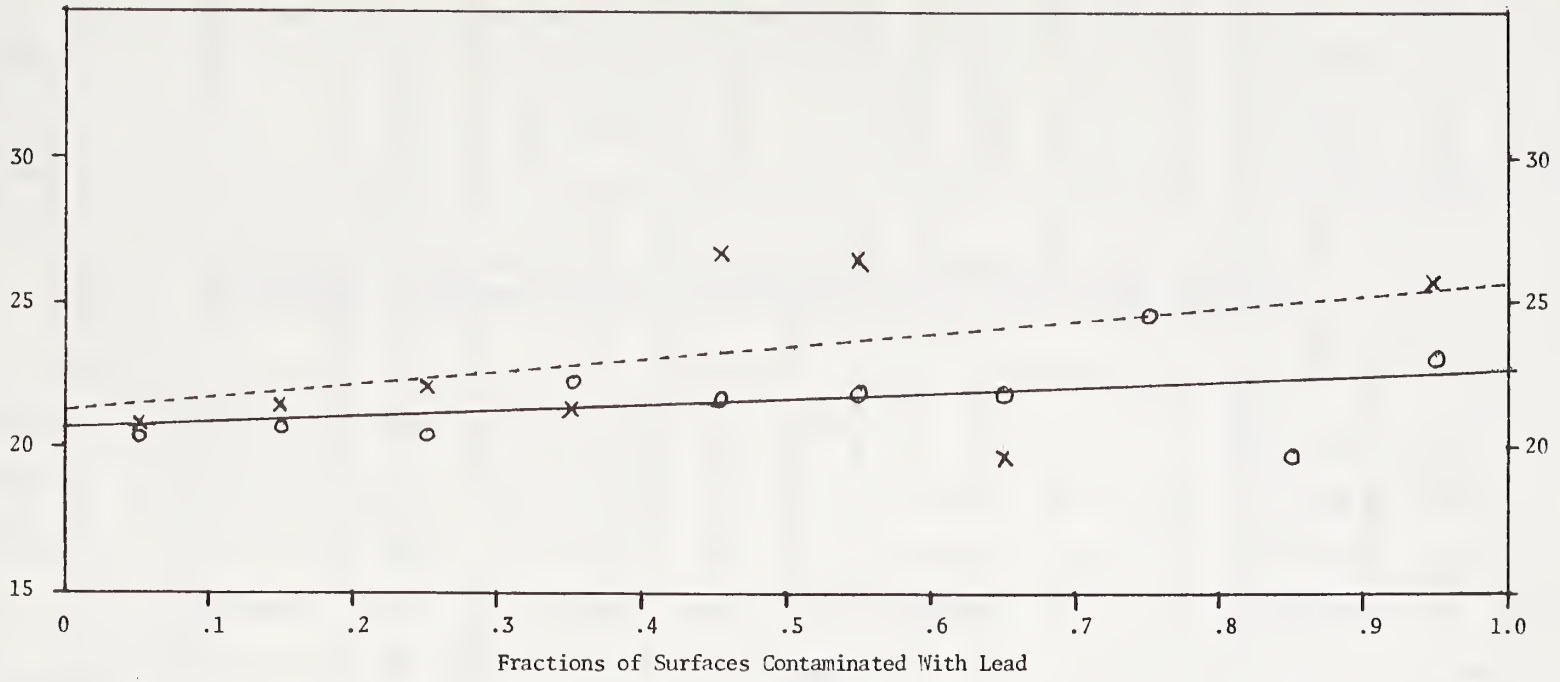
* Not all children identified by sex. Total of children may exceed sums by sex

** Not all housing identified by age. Totals for all housing may exceed sums by age of housing

*** Includes child with blood lead level of 73

Figure 9

Correlation of Children's Blood Lead Levels with the Fractions of Surfaces Within a Dwelling That Are Contaminated with Lead at Least at 2 mg/sq cm



Dashed Line = Surfaces in bad condition, namely peeling, chalking or poor substrate X - data points
Solid Line = All surfaces O - data points

pen

Table 7

Distribution of Children's Blood Lead Levels* By Age of Dwelling** Where at Least One Surface in the Dwelling Contains Lead in Excess of Specified Level

Year of Construction

Lead Levels	Pre 1940				1940-1959				Post 1959				All Dwellings			
	#	Median	Mean	Std Dev	#	Median	Mean	Std Dev	#	Median	Mean	Std Dev	#	Median	Mean	Std Dev
ALL	351***	21.2	22.4	7.0	62***	19.0	21.3	7.3	30***	15.9	17.4	4.9	456***	20.7	21.9	7.0
2 mg/cm^2	331	21.2	22.5	7.1	39	19.5	22.3	7.5	14	17.0	18.6	5.1	391	20.9	22.3	7.1
3 mg/cm^2	315	21.2	22.5	7.2	26	18.6	21.5	7.7	6	16.0	17.2	2.2	353	20.9	22.3	7.2
5 mg/cm^2	288	21.2	22.4	7.1	12	19.0	23.7	9.6					307	21.1	22.4	7.2

Distribution of Children's Blood Lead Levels* by Age of Dwelling** Where All Surfaces in the Dwelling Are Contaminated Less Than the Specified Level

2 mg/cm^2	20	21.5	21.5	6.7	23	17.5	19.5	6.7	16	14.8	16.3	4.7	65	18.3	19.5	6.3
3 mg/cm^2	36	21.3	21.8	5.9	36	20.0	21.1	7.1	24	15.8	17.4	5.4	103	19.8	20.6	6.4
5 mg/cm^2	63	21.4	22.7	6.7	50	19.0	20.7	6.6	30	15.8	17.4	5.0	149	19.6	21.0	6.6

* Blood Lead Levels in Micrograms/100 Milliliters
** Age of Children's Dwelling According to Year of Construction
*** Not all dwellings Identified By Age: Totals may Exceed Sums by Housing Type

regardless of the lead level, for houses in the same age category, the median blood lead of the children is essentially the same. Only the age of the dwelling and the median blood lead levels seem to be related. The older the dwelling the higher the median blood lead levels. This finding is more significant than the one relating the blood lead levels and increasing fraction of surfaces contaminated with lead. The correlation coefficient is about 40%. Even this coefficient is low, but it is the highest one that was found in all the statistical analyses that were done on the children's blood data.

An example of a plausible relationship which was not proven by analysis is the relation between the blood lead levels of the children and the amount of lead in the house dust and exterior dirt of the samples described in Attendix C. No correlation was apparent; the correlation coefficients were essentially zero. Although the number of test samples was only 32, any trend should have been discernible.

Two conjectures as to why occupancy of older homes may affect children's blood lead levels are that:

a) The plumbing systems of many older homes in Pittsburgh, which are still occupied, were constructed of lead piping. Thus drinking water may bear significant quantities of dissolved lead.

b) Older homes are often located in the more congested areas within a city and are likely to be exposed to heavy vehicular traffic with consequent heavier pollution by lead particulates from such traffic and from industry.

Even though the blood lead levels of children, (living in dwellings

having lead contamination levels of 2 milligrams per square centimeter of surface and higher) do not differ significantly, the possibility that the presence of lead paint does affect the children's blood lead levels cannot be completely ruled out.

All of the indicators of lead levels in a dwelling (such as, high median or mean reading of lead) for a specific surface type or room, are highly correlated with each other. The best correlation that was obtained was between the blood lead levels and the high readings.

The failure to find high correlations between blood lead levels and lead paint in housing is probably due to the data being accurately representative of normal urban background lead levels.

One of the principle objectives of this survey was to determine the blood lead levels of children living in housing which contains lead paint and to establish causal relationships between lead paint in housing and EBL's. This survey objective was achieved. The low incidence of EBL's in Pittsburgh (less than 1%) precludes any attempt to establish a causal relationship between EBL's and the presence of lead paint in housing. However, the absence of EBL's in Pittsburgh is a valid and highly significant finding which will have ramifications on future research on lead poisoning and the total lead environment.

SUMMARY

In this survey the incidence of elevated blood lead levels among the tested children was less than 1%. Since more than 80% of the children lived in the dwellings contaminated to some degree with lead paint (Table 7), it appears that in Pittsburgh at least, the presence of lead paint in housing does not per se cause elevated blood lead levels. No explanation may be advanced at this time as to why this is so. Nevertheless, the reason for this apparent anomaly is of great interest and potential value. If a causative agent can be identified as being a limiting factor in lead poisoning it might be applied to other communities where lead poisoning is a widespread and serious problem. NBS is funding continuing research in Pittsburgh, which is intended to develop and evaluate hypotheses which might explain the low incidence of lead poisoning in that city.

A weak correlation (15%) was found between the fraction of surfaces within dwellings contaminated by lead paint and the children's blood lead levels. A stronger correlation (40%) was found between the age of the child's dwelling and that child's blood lead level. Both of these trends, though statistically weak, were the strongest relationships that were found in this survey. No correlation was found between the levels of lead on the surface and the blood lead levels.

Although the blood lead levels encountered in this survey may appear to be low, the findings appear to be reliable since the analytical accuracy of the Pittsburgh laboratory has been tested and has been found to be satisfactory.

It may be necessary to match the results of the Pittsburgh survey with those of other cities and have any differences reconciled by other studies.

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7. ACKNOWLEDGEMENT

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The author thanks the staff of the National Bureau of Standards Analytical Chemistry Division for its assistance in providing porcine blood lead standards and carrying out analyses of blood samples.

APPENDIX IA

MICRO BLOOD SAMPLE COLLECTION PROCEDURE AS USED BY ALLEGHENY COUNTY HEALTH DEPARTMENT LEAD POISONING CONTROL PROGRAM

The method of drawing blood samples by finger pricking involves several steps. After the child is secure or even before, his hand may be washed to clean it of all noticeable dirt, grime and anything else, such as food stains. After that, the finger to be stuck is selected and held. The finger is initially washed with 0.1 molar hydrochloric acid. The acid is put on a sterile gauze pad and the finger is wiped vigorously. The acid is thought to mobilize the surface lead thus rendering the finger lead contamination free. The finger is then wiped with a dry gauze pad. Next, the finger is wiped with an individually wrapped sterile alcohol prep pad. After this, the finger is massaged by applying pressure from the palm of the hand towards the fingertip, pushing the blood up the fingertip. When the fingertip appears somewhat red and engorged with blood, the finger is then stuck with a blue monolet. The monolets are individually packaged finger stick needles. The first drop of blood is then wiped off with an individually wrapped sterile gauze pad. The blood is then collected with a Natelson* capillary blood collection tube of approximately 280 microliters in volume. During the blood collection procedure, care is taken to see that the tip of the Natelson* tube is held right on the point of puncture and the blood collected there so that the blood does not run down the finger and then into the tube, thereby opening possibilities for contamination. The Natelson tube fills itself through capillary action; when it is full, the blood collector picks up a Beckman Spinco* tube. The Spinco tube is a micro

*Commercially available supplies used during blood collection by the ACHD. Use of trade names in this report does not constitute an endorsement of those products.

centrifuge tube of approximately 400 microliters in volume. The blood that is in the Natelson tube is put into the Spinco tube. The child's finger is then wiped with a gauze pad and a bandage is put on the puncture. The Spinco tube is capped and labelled with the name, address and identification number for the child.

The Spinco tubes are carried in a small plastic bag back to the office where they are placed in the refrigerator. At the end of the day all blood collected that day is removed from the refrigerator and taken to the laboratory. During the transport from the office to the laboratory, the blood is not refrigerated. At the laboratory the blood is turned over to the technicians.

NOTE: The ACHD requested that the clinical laboratory provide them with lead free supplies for use during blood collection. The laboratory does not routinely test the supplies as they receive them but has tested some supplies for the presence of lead, (see Appendix 1B-1).

APPENDIX IB-1

PITTSBURGH LABORATORY DETERMINATION OF THE LEAD CONTENT OF BLOOD SAMPLING EQUIPMENT AND SUPPLIES

The clinical laboratory selected by ACHD to analyze the blood samples for lead, tested some of the supplies used in the blood collection procedure for the presence of lead using macro as well as micro procedures.

First the lead content of a pool of anti-coagulated human whole blood was assayed. The blood was then drawn into twenty (20) Natelson tubes and subsequently transferred to Spinco tubes and stored overnight. Lead assays were then determined on each tube. The alcohol in the wipes and Washkins was mixed with the control blood and assays were also made on the resultant mixture.

The results are listed below in Table IB-1.1

DISCUSSION OF RESULTS

It appears that even though NBS has found the sterile gauze, Pre-Pads and Washkins to contain significant quantities of lead, the Pittsburgh laboratory has not found that serious contamination results when these items come in contact with blood.

Table 1B-1.1

Pittsburgh Laboratory Determination of the Lead Content of Supplies Used in Blood Collection

	BASELINE BLOOD	NATELSON/SPINCO LOT # 04441	NATELSON/SPINCO LOT # 03741	WIPES	WASHKINS
1.	7*	7	9	3	6
2.	9	8	8	5	7
3.	9	8	8	4	5
4.	7	7	10	6	5
5.	11	7	10	7	7
6.	7	8	11	6	7
7.	7	7	8	6	8
8.	8	9	7	6	6
9.	10	9	7	8	6
10.	9	8	7	8	8
11.	10	7	10	7	8
12.	11	7	11	6	7
13.	11	8	11	6	8
14.	9	7	10	7	6
15.	10	9	11	7	7
16.	10	7	9	5	8
17.	11	9	10	8	10
18.	11	11	10	7	9
19.	11	11	10	6	7
20.	11	9	11	8	8

*Units in micrograms/100 milliliters

APPENDIX IB-2

NBS DETERMINATION OF THE LEAD CONTENT OF BLOOD SAMPLING EQUIPMENT AND SUPPLIES

The lead content of the supplies used during blood sampling was determined by the following procedures:

1) 0.1N HCl. - Approximately 21 g of the test solution was transferred to a 30 ml Teflon beaker.

2) Gauze Steri-Pad* - The pad was transferred to a 50 ml Teflon* beaker, 10 g of 0.1N HCl was added. The pad and solution were stirred with a Teflon stirring rod for two minutes and the pad was removed after most of the solution was squeezed out with the Teflon rod. Approximately two-thirds of the solution was recovered.

3) Prep-Pad* - The pad was transferred to a 50 ml Teflon beaker, 5 g of H_2O was added, and after stirring for two minutes the squeezed pad was removed. Approximately 4 g of solution was recovered.

4) Washkin* - The pad was treated as the Prep-Pad except 10 g of H_2O were used for four minutes of stirring. Approximately 9 g of solution was recovered.

5) Natelson Tube* - Two grams of HNO_3 (1:49), were transferred to a 30 ml Teflon beaker and this solution was used in filling and draining the tube five times by capillary action.

6) Spinco Tube* - The tube was filled with HNO_3 (1:49), allowed to stand two hours, and the solution and one water rinse were transferred to a 30 ml Teflon beaker.

7) Monolet Needle* - One gram of HNO_3 (1:49) was transferred to a 30 ml beaker, the cap was removed from the needle and the needle was held in the solution for 30 seconds.

* Trade Names

A weighed aliquot of ^{206}Pb solution, 1 g of $HClO_4$ and 0.5 g of HNO_3 were added to each sample. After evaporating the sample to dryness, the lead was dissolved in 0.025N $HClO_4$ and electro-deposited on a platinum wire anode as PbO_2. The PbO_2 was dissolved in a dilute solution of H_2O_2 and HNO_3 and the solution was evaporated to dryness.

The sample was dissolved in enough HNO_3 (1:49) to give a concentration of about 100 micrograms/milliliter. One drop of the solution was used for isotopic analysis by mass spectrometry (see Appendix III) using the silica gel procedure described in Appendix III. The total amount of natural lead in the sample was then calculated from the measured isotopic ratio of the sample and the known isotopic composition and amount of ^{206}Pb spike that was added.

The results have been corrected for a blank of 0.8 ng of lead. The individual blank values are 0.7, 0.8, and 0.9 ng.

DISCUSSION OF RESULTS

The values in the last column of Table 1B-2.1 labeled Equivalent Blood Lead requires some explanation. The values represent the amount by which the blood lead level results would rise if all the lead in the material was added to the blood sample of 0.25 milliliters.

The lead content of the Natelson tubes, Spinco tubes, and Monolets is not significantly increased when these materials are taken into the field and are opened for use.

It should be noted that while the particular test procedures used do not represent a sampling blank as such, they do indicate that some of the materials used include significant quantities of lead and that the potential for severe contamination is high. In particular the Steri-

Table IB-2.1

NBS Determination of the Lead Content of Supplies Used in Blood Collection

Material or Device	SAMPLE 1 Nanograms Lead	SAMPLE 2 Nanograms Lead	AVERAGE Nanograms Lead	EQUIVALENT* BLOOD LEAD Micrograms/ 100 Milliliters
0.1N HCl (1 gram)	2.7	2.5	2.6	1.3
Gauze Steri-Pad	81	85	83	41.5
Prep-Pad	32	28	30	15
Washkin	20	25	22	11
Natelson Tube (unopened pkg)	**	4.4	4.4	2.2
Natelson Tube (opened pkg)	4.6	3.9	4.2	2.1
Spinco Tube (unopened pkg)	0	**	0	0
Spinco Tube (opened pkg)	0	0	0	0
Monolet Needle (unopened pkg)	1.7	0.9	1.3	0.6
Monolet Needle (opened pkg)	0.0	0.3	0.1	0.05

* Potential increase in blood lead level due to contamination.

** Sample was lost during analysis.

pads, Prep-Pads and Washkins contain very large amounts of lead. However, it is not deemed possible to transfer all of the lead to the blood sample since only a small area of one surface ever comes into contact with the site of the blood extraction. How much of this lead may actually contaminate a sample is not known.

Further, the acid used in the analytical procedure to leach out the blood from the Natelson tube and Monolet, is a better solvent for this purpose than human blood is; therefore smaller amounts are likely to be leached out than the figures indicated.

On the other hand, the hydrochloric acid intended to mobilize lead on the surface of the finger, also mobilizes lead in the gauze pad which is used to apply the acid to the fingertip. Consequently wiping of the fingertip with a dry gauze pad, absorbs not only the lead in the acid but also may mechanically transfer lead from this pad onto the fingertip again. Alcohol used with Prep-Pads*, can only transfer lead from the Prep-Pad to the fingertip, since it is left there to dry before the sample of blood is taken. The amount of lead transferred by these means can be only a matter of conjecture.

*Commercial pads used by the ACHD during blood collection.

APPENDIX IC

DUST AND SOIL SURVEY

In order to identify alternative lead sources within the home environment, thirty-eight dust and soil surveys were made of those homes having children under seven years of age. As in the housing survey for lead paint, the children's blood lead data was included for possible correlation with the lead content of the dust and dirt samples. The samples were collected as follows:

Using an adhesive swatch, interior floor dust was collected from the following locations:

1) Five feet inside main entry
2) At the head of the child's bed
3) Child's play area
4) Kitchen
5) Dining area or front of TV

At the Pittsburgh laboratory, the samples were analyzed by macro and micro procedures, to determine the average level of lead content.

Exterior soil was sampled using a similar procedure. Soil samples were taken from seven and one-half feet in front of the main entry and five feet diagonally from each of the structure's four corners. If these areas were paved, such as sidewalk or driveway, then samples were taken from the side or back soil at the approximate center-line of the structure.

In order to validate the laboratory procedures, duplicate interior and exterior samples were taken from arbitrarily selected homes of some tested children. Two samples were taken at each of the locations listed

Figure IC-1.1

Lead Content of Pittsburgh House Dust Samples

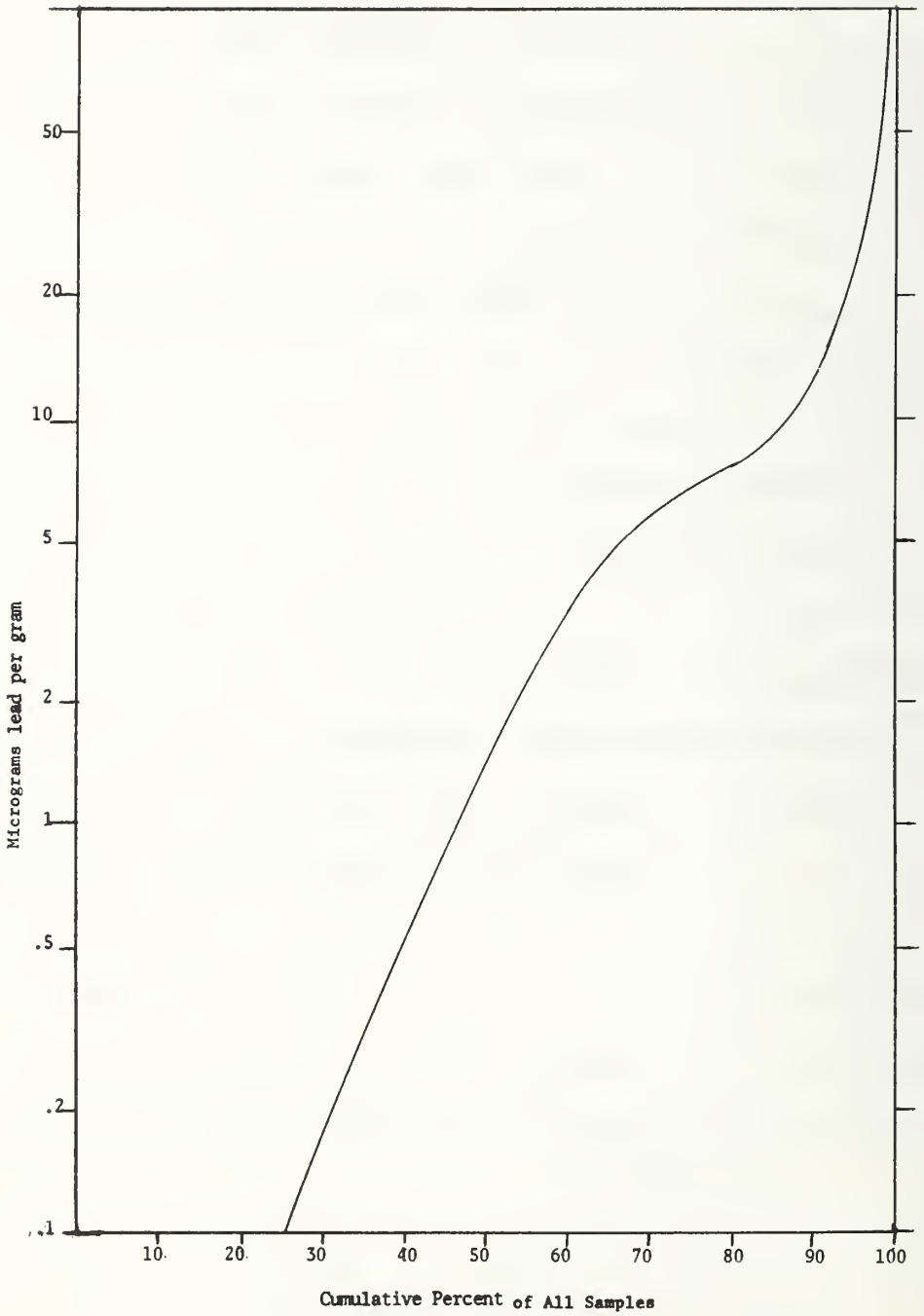
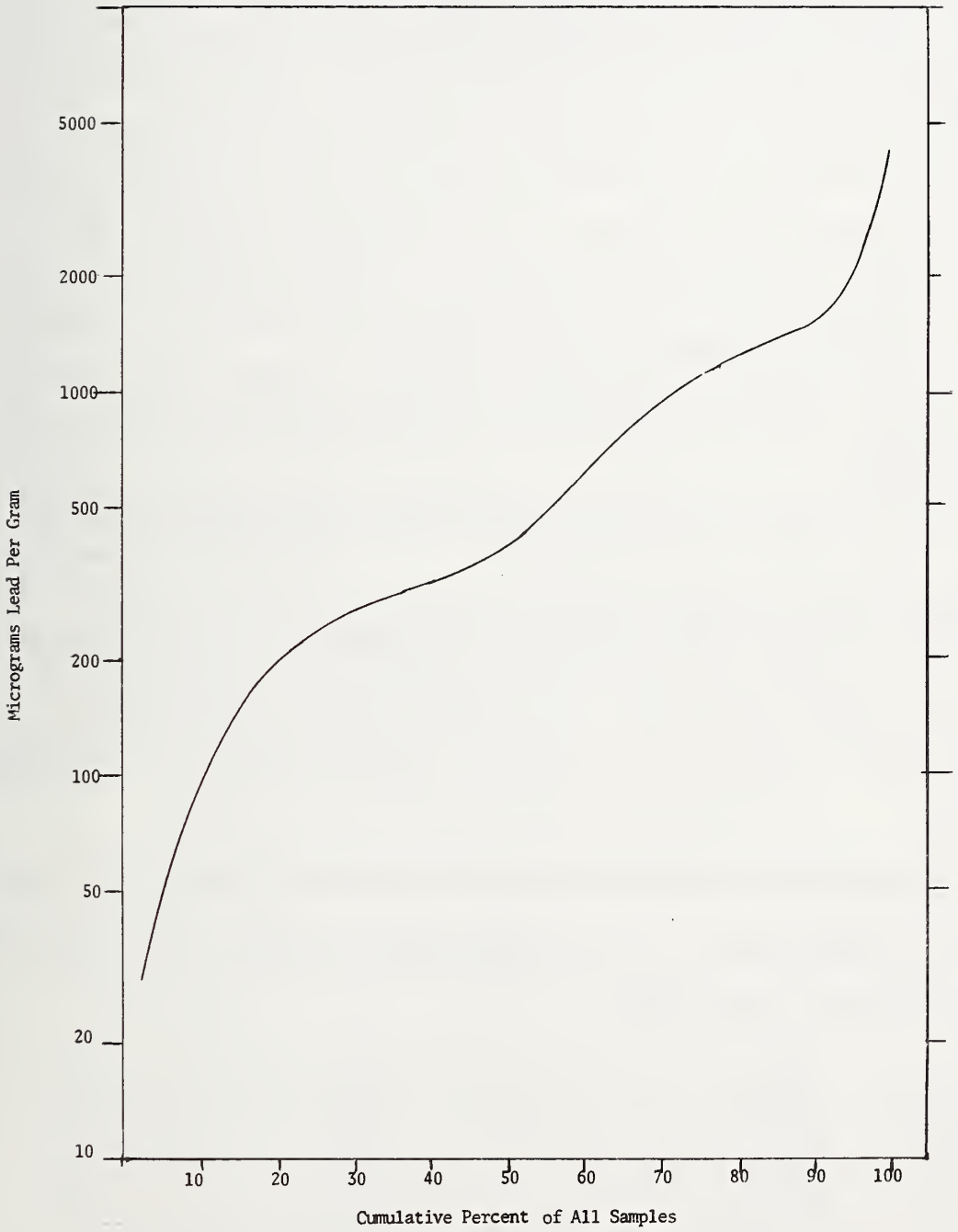


Figure IC-1.2

Lead Content of Pittsburgh Dirt Samples



above. Although the basic data was not made available to NBS for analysis the average results for the duplicate analyses are shown in Figures IC-1.1 and IC-2.1

The parameter 'cumulative percent' used in these figures is defined as the percent of the values, of the whole sample population, that are equal to or less than the indicated value at the specified cumulative percent.

Thus, for dirt at the cumulative percent of 40, 40 percent of all the dirt samples had a content of 310 micrograms of lead per gram of dirt or less or, conversely, 60 percent of the dirt samples had a lead content of 310 micrograms per gram or more.

By definition, at the cumulative 50 percent level, the value indicated is the median.

As can be seen, the lead content of dust varies widely with a median value of 1.8 micrograms/gram.

For dirt the values range from 30 micrograms of lead per gram of dirt to a high value of 4000. This latter amount is equivalent to about 9 lbs. of lead per ton of dirt. The median value is 380 micrograms per gram.

No correlation was found between the levels of lead in the house dust and exterior dirt of the dwellings sampled and the blood lead levels of the children living there.

APPENDIX ID

WEIGHT LOSS OF FROZEN PORCINE BLOOD STORED IN SPINCO TUBES

Six samples of porcine blood in Spinco Tubes were checked for weight loss after three weeks and after four months of storage in a freezer. These samples were weighed after allowing them to warm to room temperature and three empty tubes were carried along for tare correction. These six samples (0.12-0.37 g) lost an average of 0.17 percent after storage for four months.

It had been observed by visual inspection that some other blood samples had dehydrated when stored in a freezer for a period of several months. Those samples, showing visual dehydration, were stored with only one or two tubes within a 30 ml or 50 ml Teflon beaker. The six samples in this study were all stored together in a 30 ml Teflon beaker covered with Parafilm.

The Spinco Tubes appear to be suitable containers for storage of blood in a freezer for periods of several weeks if several are stored together to conserve the moisture loss, in a plastic bag or a covered beaker.

Weight Loss of Porcine Blood in Spinco Tubes

Tube #	Weight of Blood Sample	Weight Loss	
		Three Weeks	Four Months
	g	%	%
11	0.29	0.07	0.17
12	0.12	0.06	0.21
14	0.23	0.01	0.13
15	0.37	0.01	0.11
16	0.24	0.03	0.19
17	0.25	0.03	0.14

APPENDIX II

ANALYTICAL PROCEDURE EMPLOYED BY THE CLINICAL LABORATORY SERVING ACHD

This laboratory is certified by the Center for Disease Control (CDC) as performing satisfactory analyses of lead in blood. Periodically they analyze standard reference samples sent them by CDC for validation.

This laboratory employs a variation of the Delves Cup procedure as modified by Eugene D. Olson and Peter J. Jatlow [6], to determine the lead levels in blood.

LEAD IN BIOLOGICAL MATERIALS
TYPE C PROCEDURE [7]

APPARATUS

1. Vacutainer* tubes, heperanized (Becton-Dickinson* No. L3200XF 313)
2. Polyethylene bottles, screw capped, 4 oz.
3. Homogenizer (Sorvall Co. Omni-Mixer-Om* Model 17105) equipped with a 50 ml stainless steel chamber assembly (Model 17077)
4. Shaker (Eberbach Corp.*)
5. Centrifuge tubes (Fisher Scientific* Cat. No. 5-558 or 5-558-5), 50 ml.
6. Centrifuge (International* Model UV)
7. Spectrophotometer, atomic-absorption (Perkin-Elmer* Model 303) equipped with a lead Intensitron lamp and digital reader, (Perkin-Elmer* Model DCR-1)

REAGENTS

All chemicals used should be analytical reagent grade. All aqueous solutions are prepared with double distilled water.

1. Ammonium pyrrolidine dithiocarbamate -- Triton* X100 reagent
   Mix equal volumes of a 2% solution of APDC and a 5% solution of Triton X100.
2. MIBK (Methylisobutylketone), water-saturated
   Presaturate the solvent with distilled water prior to use
3. Lead stock solution, 100 mg/liter
   Dissolve 0.1599 g of dried lead nitrate in 1 liter of distilled water containing 1.0 ml of concentrated nitric acid.
4. Lead reference solution, 1 mg/100ml
   Dilute 10.00 ml of the lead stock solution to 100 ml with distilled water.

PROCEDURE

Preparation of the Specimen

1. Mark the exact level of the blood on the Vacutainer* tube in which the specimen has been received. A sample size of 2.0 ml is required.
2. Pour the entire blood specimen into a 4 oz. plastic bottle. Note whether the specimen is clotted. If the sample is clotted request new sample.
3. Rinse the collection tube by adding 1.0 ml of APDC -- Triton* X-100 reagent and shake its.
4. Mix and let stand for 10 minutes.
5. Add 2.0 ml of water saturated MIBK and shake for 5 minutes on Eberbach* shaker.

*Trade names or manufacturers of scientific instruments.

6. Centrifuge the tube @3000 rpm for 10 minutes to separate the layers.
7. Pipette upper layer into acid washed Vacutainer* and a stopper.
8. Aspirate the upper MIBK into the atomic absorption spectrophotometer.

PREPARATION OF REFERENCE SAMPLES

1. To 4 oz. plastic bottles containing solutions with known lead concentrations add the following reagents in the order listed below:

Reagent volumes (ml) required for reference solutions

Reagent	Reference Lead Concentration µg/100 ml			
	0	30	60	120
Lead reference solution	0.0	.06	.12	.24
Water		1.94	1.88	1.76
APDC-Triton* X100 Reagent	1.0	1.0	1.0	1.0
Water saturated MIBK	2.0	2.0	2.0	2.0

2. Shake each solution for 5 to 10 minutes.
3. Transfer each solution to a 50 ml centrifuge tube.
4. Centrifuge the solution for 10 to 15 minutes.
5. Remove the upper layer, which contains the extracted lead-APDC chelate from each sample and aspirate it into the flame of the spectrometer.

MEASUREMENT OF UNKNOWN AND REFERENCE SAMPLES

1. Set the following controls of the atomic-absorption spectrophotometer as appropriate:

   Slit
   Range
   Gas mixture
   Wavelength
   Aspiration rate
   Air pressure
   Averaging switch
   Noise suppression
   Scale

   Allow a warm up time of 1 hour for the instrument and 30 minutes for the flame. Adjust the amount of acetylene in the flame while aspirating a water saturated solution of MIBK, so that there is a slightly visible orange tint to the flame.

2. Determine the absorbance of the specimen. After performing 25 analyses check the absorbance with reference samples, make the necessary corrections for instrumental drift or change in the flame characteristics.

3. Plot the absorbance of the reference samples against their respective lead concentrations, then draw standard curve from the data obtained.

CALCULATION

Determine the lead concentration in the specimen by comparing its absorbance with that of a suitabel reference sample or a standard curve prepared from the reference sample suggested above.

ACCURACY AND PRECISION

In the range from 25µg to 120µg per 100 ml, the relative error is on the order of 5%, with a standard deviation of approximately 4µg per 100 ml. Results obtained by this method and those obtained by the dithiozone procedure yield comparable data.

INTERFERING SUBSTANCES

At a wavelength of 283.3 nm there is no interference from other metal ions. Therapeutic blood concentrations of EDTA, used in the treatment of lead poisoning, also do not interfere with lead determinations.

COMMENT

The method requires no pipetting or aliquoting of blood, since all volumes used are based on the total volume of blood collected. A technician can analyze up to 50 samples per day by this method including preparation of solutions, calculations and reporting data.

QUALITY CONTROL PROCEDURES

Stock standard from Lead Nitrate per procedure requirements.

Working standards made from stock solution: 20, 40, 60, 80, 120, 160 micrograms/100 milliliters.

Standard curve run before each group of patients.

Eight (8) controls used with every six (6) patients.

a) Four aqueous controls
b) Four whole blood controls loaded with lead

LEAD LOADED WHOLE BLOOD QUALITY CONTROL POOL

POOL PREPARATION

Lead loading standard - 100 micrograms/milliliter

Collect 500 ml pooled whole blood or use outdated blood bank blood (RECOMMENDED - if phosphate used as additive make sure citrate also used.) Analyze pool. Add sufficient lead standard dropwise with stirring and continue to stir for 30 minutes to give value between 40-50 micrograms/100 milliliters.

Blind Control analysed as submitted by CDC and CAP.

All Delves Cups pre-standardized by Perkin-Elmer*, then restandardized at the laboratory.

ALL SAMPLES RUN IN DUPLICATE

The equipment is adjusted so that the values found for the blanks automatically are nulled out.

*Manufacturer

APPENDIX III

The NBS Method for the Determination of Sub-Microgram Samples of Lead Employing Mass Spectrometry

DISCUSSION

Samples in which the amount of lead is one microgram or less, such as in the blood samples of the Pittsburgh survey (0.1μg or less), require extraordinary care in handling, in cleanliness, in reagent selection and attention to details not important in good analytical work with larger sized samples.

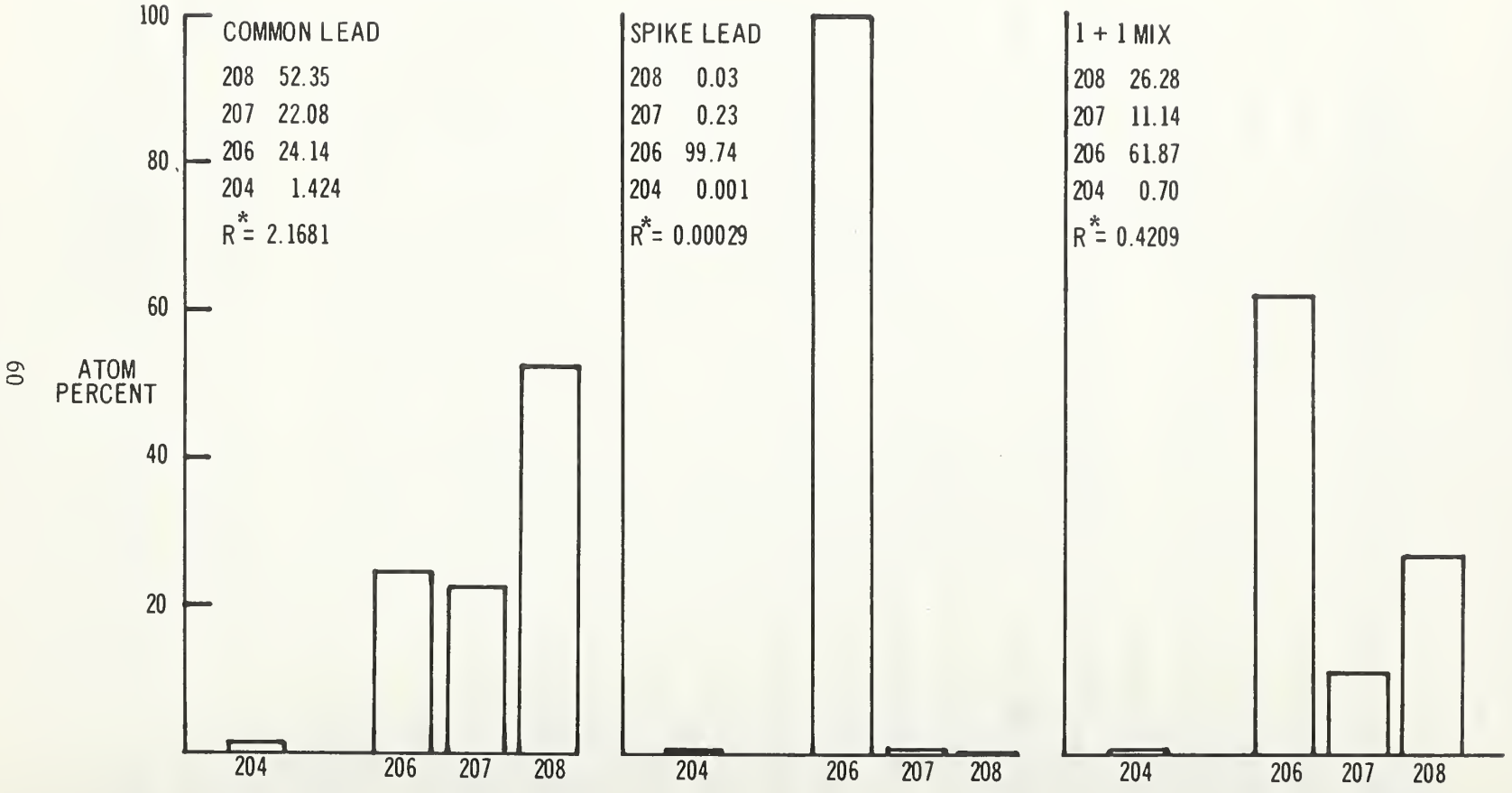
A method has been developed at NBS [8] involving the dilution of the lead in the blood sample with a specific lead isotope; separation of the total lead from the sample by electro deposition and the subsequent determination of the lead in the orginal sample after anlaysis by isotope ratio mass spectrometry. The combined procedure is applicable to samples containing from 10 micrograms to less than 10 nanograms (0.01 μg). The electro deposition is more than 95% efficient at these levels while the mass spectrometric procedure premits a precision of 0.1% for the measured isotope ratios.

Lead as found in nature, and in blood, is largely composed of three isotopes of atomic weights 208, 207 and 206 respectively and a trace isotope of atomic weight 204. The isotope compoistion of a typical lead sample is shown in Figure III-1. Lead of atomic weight 208 (Pb208) is the major constituent.

It appears that the fractions of these isotopes of lead in blood does not vary much from person to person. For analyses permitting accuracies to within a few percent, the fraction of Pb208 and Pb206 may be assumed to be 0.5209 and 0.2519 respectively. NBS selected these values

Figure III-1

Isotope Composition of Natural and Spike Lead Samples



$$*R = \frac{\text{Atomic Percent } {}^{208}\text{Pb}}{\text{Atomic Percent } {}^{206}\text{Pb}}$$

as being representative on the basis of determinations of the actual fractions of these isotopes in the blood of several persons. Only when greater analytical accuracy is required must the actual isotope composition be determined for each sample prior to the addition of the lead isotope dilutant.

The 'spike' lead isotope, was largely composed of PB206*. The actual composition of one such sample is also shown in Figure III-1 as well as the result of a one to one mixture of the typical lead sample and the 'spike' lead.

Critical to the analytical procedure is the lead extraction process where the lead in the sample after dilution is separated from the bulk of the blood sample. It is critical in that unless 95% or more of the lead is extracted the analytical accuracy would be reduced accordingly. The preparation of the analytically ultra pure reagents used on this procedure are described on the above citation and in more detail in reference [9].

The lead extraction procedure is performed in two steps. In the first step the lead is removed from the bulk of the blood by cathodic deposition, redesolved and then in the second step anodically deposited as PbO_2.

EXTRACTION OF LEAD FROM THE BLOOD SAMPLE

The blood samples as received by NBS were frozen in Spinco Tubes. After thawing, all the samples contained blood clots, making the samples non-uniform in composition: precluding sample subdivision. Thus each

*Obtained from Isotopes Division, Oak Ridge National Laboratory of Union Carbide Nuclear Company

sample had to be analyzed as a unit.

Each tube was weighed before and after the blood was transferred to a 30 milliliter Teflon beaker. About 10 milliliters of redistilled water was used to promote the transfer.

A 0.1 gram aliquot containing 14.7 micro grams of the 206 isotope of lead per gram of solution was added to the blood samples.

One gram each of ultrapure nitric and perchloric acid was added and the samples were decomposed by heating, and evaporated to dryness.

The samples were redissolved in 20 grams of 0.025N perchloric acid, after which the lead was removed from solution by electro-deposition for 4 to 5 hours at 3.5 volts onto platinum electrodes.

The deposited lead was redissolved in 0.025N perchloric acid and lead deposited as lead dioxide was dissolved in a few drops of hydrogen peroxide and nitric acid solution and was finally evaporated to dryness.

The isotope dilution measurements were made on this deposit.

The average total analysis blanks were 0.67 nanograms ranging over less than 0.2 nanograms. The blank was about 1.5 percent of the total lead in the samples.

The reagents used are of the ultrapure variety that test at less than 0.1 nanograms per gram of reagent.

COMPUTATION OF THE AMOUNT OF LEAD IN BLOOD SAMPLE

After the lead extraction procedure the ratio of Pb208 and Pb206 is measured by the mass spectrometric procedure described in reference [8]. Knowing this ratio and the amount of Pb206 added as a dilutant, it is possible to compute the amount of lead in the original blood sample.

The following formula was used:

$$L = W \frac{(S_{208})\ (R) - S_{206}}{N_{206} - (N_{208})\ (R)} \cdot \frac{N}{T}$$

L = Weight of lead in original sample
W = Weight of added spike lead
S_{208}= Fraction of 208 Pb in spike
S_{206}= Fraction of 206 Pb in spike
N_{208}= Average fraction of 208 Pb in blood
N_{206}= Average fraction of 206 Pb in blood
R = Measured ratio 208 Pb to 207 Pb after adding spike lead
N = Atomic weight of natural lead in blood
T = Atomic weight of spike lead added to blood

For the quantities above the following values were used:

S_{208}= .000287
S_{206}= .9974
N_{208}= .5209
N_{206}= .2519
Atomic weight for N = 207.2
Atomic weight for T = 205.9

Substituting these values in the formula results in the following:

$$L = \frac{W\ (.000287)R - .9974}{.2519 - (.5209)R} \cdot \frac{207.2}{206.98}$$

APPENDIX IV

COMMENTS ON LOWER VALUES OF BLOOD LEAD LEVELS AFTER RETEST

Several reasons may be advanced for the predominantly lower values that were obtained after retest. Four possibilities are advanced and the merits of each are reviewed below.

(a) The Pittsburgh laboratory exercised greater care during the repeat analyses.

This argument is easily disposed of since the repeat blood samples were not distinguished from the routine screening samples. The laboratory was not informed as to which samples were repeat ones.

(b) Better care was exercised during blood collection.

It does not appear that the contamination of blood samples with lead was a problem during this survey, However, it is possible that the exercising of greater care could lower contamination and consequently result in lower blood lead values.

(c) Children's blood lead levels decreased in the interval between the first screening and the subsequent retest.

Generally less than a month elapsed between the blood samples. It does not appear likely that the blood lead levels would change greatly in this relatively short time interval, or that if they changed they would uniformly tend to fall.

Since the parents of these children had no a priori reason to suspect that their children seemingly had elevated blood lead levels, it does not appear to be likely that either the children's behavior or activity differed significantly from usual or that the parents supervised them more closely.

(d) The bulk of the initial high readings may be attributed to inherent limitations of analytical accuracy.

This last conjecture is the one most likely to be correct and the rationale for this conclusion may be supported by statistical arguments.

To simplify the discussion, the blood lead levels of all the children are assumed to be the same. Later the arguments may be broadened to include a range of blood lead levels.

If one performs an unbiased analysis of the total population of identical blood lead composition, preserving the identity and the quantity of each sample for possible retest, one would obtain a set of values normally distributed about a mean value, m, and would have a standard deviation value, s. One-sixth of the values would exceed m by one standard deviation and an equal number would fall below m by the same amount, s. The mean value would approximate the true blood lead value. The extreme values obtained would not be correct but would be the unavoidable results of limited analytical accuracy.

Now if only the high valued blood samples were to be retested and since the blood samples would be in no way different from the original population of samples, the results of the retest should approximate the results for the population as a whole. Namely, the retest values should be normally distributed about the same mean value, m, and should have the same standard deviation, s. Now only one-sixth of the retest values would now exceed m by as much as one standard deviation.

This reasoning applies to the low values as well. The retest of extreme valued samples in general should tend toward the mean value. Thus if high values are due to analytical inaccuracy the retest values

should tend to drop. This tendency also applies to a mixture of populations. As long as the high values are higher than actual and exceed the mean of their respective populations, the tendency would be for the retest values to drop. On the contrary, the retest values of the samples that initially tested below their respective means would tend to rise. In short, there is a tendency for the retest values to converge toward their respective means.

The mean blood lead level of the tested children was 21.9 micrograms per 100 milliliters with a standard deviation of 7.0. Initially, 15 children or 3.3% of the tested children were identified tentatively as having blood lead levels in excess of 40.0. This number is so small that most or all of the high values could be in reality antifacts of the analytical process.

While the tested children certainly did not have identical blood lead levels, the above arguments apply since the aggregate results may be considered to be a superposition of the results of a range of populations of tested children. Each such population would consist of children actually having the same blood lead level, and where the values for each population would have their own mean and standard deviation. It is not possible to isolate each such population from the aggregated results for all the tested children.

In summary, based upon statistical arguments, it is reasonable to accept the proposition that, due to the small number and the small magnitude of the high values obtained on initial testing, the high values were probable analytical artifacts.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

A survey was conducted in Pittsburgh, Pennsylvania to estimate the incidence of lead paint in housing and to develop a survey methodology that could be used in other metropolitan communities for that purpose. A secondary objective of the survey was to determine whether a causal relationship could be found between blood lead levels of children aged 7 years or less, living in the surveyed dwellings and the presence of lead paint in those dwellings. This report deals with the latter objective. For the children tested in Pittsburgh, the incidence of elevated blood lead levels defined as 40 micrograms of lead per 100 milliliters of blood or greater, was found to be less than 1%, too low to permit the establishment of a causal relationship. There was a significant correlation between the blood lead levels of the children living in the older homes and the fraction of contaminated surfaces within the dwellings. In addition, there was a significant correlation between the blood lead levels and the age of the dwellings in which the children resided. This correlation appeared to be independent of the lead paint levels in the dwellings. This report presents a summary of the survey procedures, the blood lead measurement process and associated problems and the more significant results of the analysis of the housing/blood lead data obtained in Pittsburgh.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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